1972

The mio-eugeosynclinal thrust interface and related petroleum implications in the Sason-Baykan Area, Southeast Turkey

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THE MIO- EUGEOSYNCLINAL THRUST INTERFACE AND RELATED PETROLEUM IMPLICATIONS IN THE SASON-BAYKAN AREA, SOUTHEAST TURKEY

by

ISMAIL ÖZKAYA, 194

A DISSERTATION

Presented to the Faculty of the Graduate School of the

UNIVERSITY OF MISSOURI-ROLLA

In Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

in

GEOLOGY

1972

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ABSTRACT

A detailed investigation of the stratigraphy, structure and petroleum geology of the Sason-Baykan region in 600 square km area of the thrust belt of southeast Turkey was completed at a scale 1: 25 000. Geosynclinal sediments within the area were redated.

Results of field study indicate a massive plate of metamorphic rocks and crystalline limestones was thrust southward over geosynclinal sediments. These in turn were thrust over the southern marginal basin deposits. A stratigraphic sequence of the allochthonous geosynclinal sediments was reconstructed and correlated with the autochthonous Tertiary section. Contrary to earlier views the allochthonous sediments and accompanying igneous rocks are not Upper Cretaceous-Paleocene but of Oligocene-Miocene age. Radioactive age determination of two spilite samples from this series confirmed this result. These facts suggest that eugeosynclinal conditions and submarine basic volcanic activity persisted until the end of Miocene in the Foothills Belt of southeast Turkey.

Uplift and sedimentation migrated from north to south in time. Geosynclinal type backdeeps existed to the north on the Bitlis Massif during Upper Cretaceous-Paleocene times. After a quiet period of shallow seas in Eocene time the northern areas were uplifted and the frontal portion of the Massif downwarped. This frontal Lice-Baykan geosyncline was linked by a northwest trending hinge to a southern marginal basin.

A non-clastic stage of sedimentation was followed by a clastic stage in the Lice-Baykan geosynclinal and southern marginal basin. Lice grey marls, shales and graywackes accumulated on the southern

outer flanks of the northern geosyncline. Red marl, flysch and red clastic sequence of the Sason-Baykan group with accompanying basic igneous rocks was deposited in the inner eugeosynclinal portions of the same trough. Germik evaporites and Selmo red sandstones were deposited in the southern marginal basin. The hinge belt was the site of deposition for Silvan reef limestone and lower Selmo salts. The south to north facies change of these deposits reflect changing tectono-environments from moderately negative unstable shelf into deeply subsiding eugeosynclinal trough.

Major diastrophism occurred at the end of Miocene and resulted in southward thrusting of the geosynclinal sediments and plates of the northern massif.

Orogenic activity may have also migrated southward in time. Field criteria suggest a possible early Oligocene thrusting in the northern areas of the Bitlis Massif where Upper Cretaceous-Paleocene backdeeps had been present. Metamorphic rocks and crystalline limestones were thrust over these early geosyncline sediments. Today the latter occur as a tectonic slice within the allochthonous metamorphic block. A Late Miocene orogeny affected the southern frontal areas of the Bitlis Massif where the Lice-Baykan geosyncline was present.

Tangential compressional forces were the main driving mechanism of deformation. Thrusting and folding took place under the action of north to south oriented stress. A final stage of tension resulted in east-west normal faults. Gravity sliding played a minor role in outlining the structure of the area but did result in the emplacement of a few exotic limestone and serpentine blocks within the geosynclinal sediments.

Despite its setting within a geosynclinal zone and thrust belt, the area does have oil potential. The presence of source rocks, reservoir horizons, cap rocks and broad fold structures within the autochthonous block of Tertiary sediments, absence of Upper Cretaceous subsurface intraformational ophiolites, and the surficial nature of thrust plates which cover the Tertiary section are all favorable factors.

ACKNOWLEDGEMENT

I express my grateful thanks to Dr. Paul Dean Proctor, Director of Water Resources Research Center, and professor of geology and geological engineering, Department of Geology and Geophysics at the University of Missouri-Rolla, for suggesting the thesis topic and for his continued advice and guidance. My special thanks are due him for his visit to my field area in Turkey, and supervision and useful suggestions offered during that period.

The Turkish Petroleum Corporation provided financial support, transportation and other facilities during the field work in Turkey, and also met the expenses connected with the radioactive analysis of spilite samples. I express my gratitude for the help given. I also thank the Turkish Petroleum Corporation for the permission I was granted to use their geologic information pertinent to the area of investigation.

I am also grateful to Mr. Okan Ozdemir, geologist and district coordinator of the exploration group, Turkish Petroleum Corporation, for the enthusiastic interest shown by him in my work and for all help rendered by him.

I am indebted to Prof. Melih Tokay, Chairman, Department of Geological Engineering, The Middle East Technical University, Turkey, Mithat Tolgay, head, geological and geophysical exploration group, Turgut Bolgi, chief of the geological exploration group, Zeynel Malal, chief geologist and Orhan Gokmenler, general manager of the exploration group of the Turkish Petroleum Corporation, for the assistance given, and facilities provided.

I extend my thanks to Mrs. Fikriye Gungor, paleontologist, Turkish Petroleum Corporation, for her critical micropaleontologic study of my rock samples for age determination.

It is with a deep sense of gratitude that I express my thanks to the Scientific Research Council of Turkey for providing a generous scholarship and defraying part of my travelling expenses. My appreciation is extended to the V. H. McNutt Memorial Foundation of the Geology Department of the University of Missouri-Rolla for providing financial aid to cover part of my travelling expeses.

My thanks are also due to Fahri Turan, driver, Turkish Petroleum Corporation, for the patience with which he shared the hardships of field work with me. Also acknowledged are several people of the Turkish Petroleum Corporation for their generous help in laboratory work and drafting.

Dr. Don Frizzell of the University of Missouri-Rolla, and Dr. Orville Bandy of the University of Southern California kindly identified and confirmed some microfossils.

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I. INTRODUCTION

A. Foreword

A major thrust belt, trending approximately east-west for 600 kms, limits the southeastern Turkey Borderfolds zone on the north. With typical foothills fold structures, this belt is a link between the gently folded shelf zone and the Taurids orogenic complex.

The Borderfolds Zone was the site of continuous deposition from Cambrian until late Pliocene with only a few periods of uplift and mild deformation. The resulting thick accumulation of sediments are oil bearing, and several productive fields exist in the area. Oil is produced from Upper Cretaceous-Paleocene Raman, Garzan, and Sinan reef carbonates and less commonly from Lower-Middle Cretaceous Mardin limestones. Some of the most productive oil fields are situated proximal to the hinge line between the unstable shelf of the Borderfolds Zone and the northern troughs. The hinge line follows the thrust front approximately along the Foothills Belt.

B. Purpose and scope of investigation

The purpose of this investigation was fourfold;

1. To determine the stratigraphic sequence and depositional history of the allochthonous geosynclinal sediments.

2. To determine the structural and tectonic nature of the thrust belt.

3. To investigate the tectonic and stratigraphic nature of the transition zone from the southern unstable shelf area into northern eugeosynclinal troughs.

4. To study and predict the oil potential under the area covered by thrust sheets.

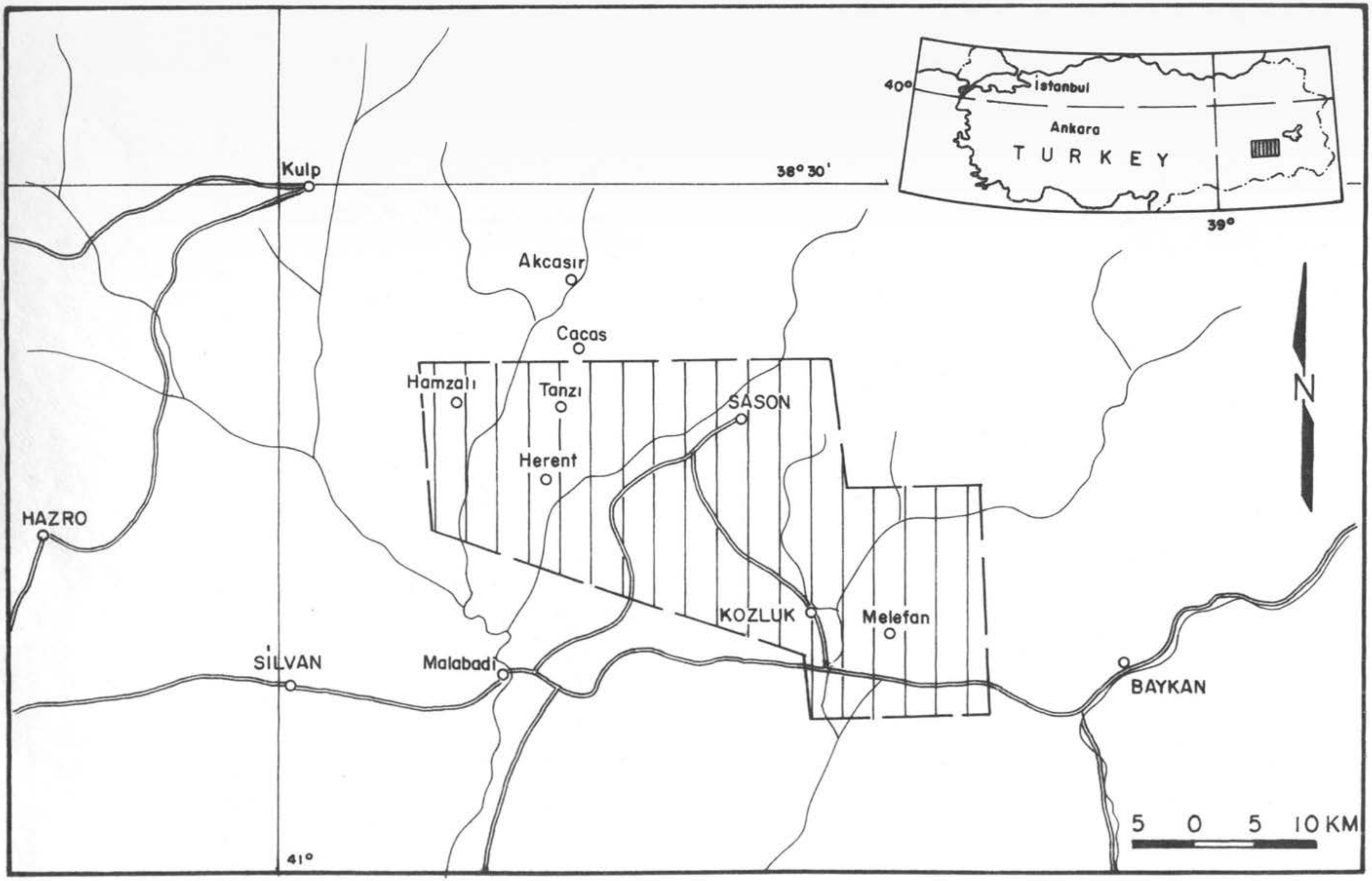

Figure 1. Index map of the Sason-Melefan area, southeast Turkey.

An area of 600 square kms, bordered by Hamzali, Sason, Kozluk and Melefan was selected for field study for the following reasons:

1. The characteristics of the foothills structures with extensive lateral thrusting, imbricate faulting, klippen and fenstern are well displayed in this area. These structures, while little studied, made the area especially good for field investigation.

2. A hinge line separating the Miocene marine Lice sediments on the north from the southern transitional Selmo formation trends through the area. This hinge line lies at the eastern extension of the well-defined Hazro uplift and generally follows the thrust front in the Sason-Melefan area. These relationships suggest that the dividing line of the Miocene facies might be the latest expression of a major hinge belt which separated an unstable shelf zone from the eugeosynclinal troughs during Mesozoic and Tertiary times.

Evaluation of the oil potential under the thrust sheets covering the northern areas, as well as the solution to several stratigraphic and structural problems relating to the thrust belt depend on the understanding of this transitional zone. The uplifted hinge-line belt has a special interest in itself because the major oil fields in Iran and Iraq to the east occur on the hinge line between the unstable shelf and the troughs. This also appears to be the case for Turkey. However, the hinge zone was not affected by diastrophic movements in Iran and Iraq, while in Turkey, the focus of diastrophism was very close to it and most of the time the hinge belt was directly involved in thrusting.

3. Some fold structures in the lower thrust plate parallel the thrust front, while some others trend transversely to it. Broad symmetrical fold structures occur side by side with asymmetric overturned

folds. An understanding of these structural relationships should help to explain the mechanism of thrusting and folding in this region. The folds and thrust sheets may have a bearing on the oil potential in the area. If, for example, folds in the Tertiary autochthonous sediments are due to drag effect of thrusting, such structures should be superficial, disharmonic and have low potential for commercial oil accumulation. If, however, folding occurred before and after the thrusting, such structures have depth continuity and have greater potential for oil entrapment.

5. Representative sections of the geosynclinal sediments occur within this area, permitting a reconstruction of the depositional sequence, although these sediments are best exposed in the Baykan and Lice regions outside the research area.

Due to the limited time and large size of the project area the Baykan and Lice regions were only briefly studied. Only the essential factors pertaining to the objectives of this study were investigated. From the results obtained it is apparent that the geologic problems of the extensive and complex thrust belt are more numerous and diverse than could be resolved within the framework of a single research project. Much remains to be done. Nevertheless this study is submitted with the hope that it is a relevant contribution to a general understanding of the southeastern Anatolian thrust belt.

C. Method of study

A study and interpretation of the structural elements, stratigraphy and detailed mapping of a 600 square kms area at a scale of 1: 25 000 constitutes the major part of this work. Due to the structural complexity, rapid facies changes and the vertical repetition of lithologies, identification and correlation of formations within the allochthonous geosynclinal sediments proved difficult. For purposes of this work, the sedimentary rocks of the upper thrust plate were grouped and mapped under three major tectono-environmental associations. Sedimentary groups or traceable lithologies were also mapped whenever possible.

Aerial photographs were most useful in providing a broad view of the area. These were used as complementary tool to field mapping. The photogeologic mapping and interpretation consisted of identification and description of each mappable unit, preparation of a photo-key and a trial transfer of such information to the base map by inspection before and in conjunction with field work. In some cases more geologic information could be obtained from aerial photo-pairs on the structure of the area than in actual field mapping. Detailed field work was carried out to detect some of the obscure structural relationships which were readily observable on the photos. In addition to the photo and field geologic mapping, more than 600 rock samples were collected for paleontologic and petrographic studies.

Laboratory work consisted of preparation of thin sections, micropaleontologic and petrographic studies and age determinations of about 200 selected rock specimens. Absolute age dates were obtained for two spilite samples. Additional laboratory work included drafting of maps, preparation of cross-sections, index maps and photos. Cross-sections of the broad structural relationships are drawn to scale, other sections which illustrate stratigraphic relations as observed in the field have approximate scale

The field work was completed in eight months during the summers of 1970 and 1971. Thin sections were prepared and studied for age determinations in the laboratories of the Turkish Petroleum Corporation in

Ankara, Turkey, during January 1972. A part of the drafting work and literature review were also completed in the same period in Turkey.

The outlines of the stratigraphy, structure and petroleum geology of southeast Turkey are based on published information. The main body of the dissertation is presented in the chapters on stratigraphy, structure and petroleum geology and is the result of the field and laboratory work carried out by the author. Drilling and other unpublished geologic information of the Turkish Petroleum Corporation pertinent to the area of investigation was used to a certain extent. References on the drilling are given only in the beginning to avoid repetition.

D. Location and geography

The area is situated between 41° 08' and 41° 35' E long., and 38° 10' and 38° 20' N lat. in the Diyarbakir. Siirt and Bitlis provinces of southeast Turkey. It extends roughly west of Batman river to the east of Garzan river. Sason, Bahemdan, and Hamzali border the area on the north and Herent, Kozluk, and Melefan on the south (figure 1). The area is at the junction of the southern flank of the Bitlis Massif on the north and the Diyarbakir plains on the south. The sharp change in topography from the high elevation and rugged mountains into the gently undulating plains reflects the change from the Foothills Belt into the Borderfolds Zone. The thust fault zone corresponds to the geologic as well as the physiographic border.

The northern and central parts of the area, which are underlain by metamorphic rocks and crystalline limestones have an average elevation of 1500-1700 meters. Peaks rise above 2500 meters. The eastern and western parts of the area consist of allochthonous eugeosynclinal sediments. These are characterized by rounded hills and an average elevation of 1200-1300 meters. South of the thrust front, the plains are underlain by Tertiary deposits of low relief character and an average elevation of 800 meters.

Garzan, Sason, and Batman rivers and their tributaries all flow generally southward and form a broad dendritic pattern in the region.

The climate is continental arid with dry hot summers and humid cold winters. Vegetation cover is thin, but is denser towards the north. Population is low and widely scattered. Small settlements are controlled by the irregularly distributed areas of fertile land adjacent to springs or small creeks. Apart from the Malabadi-Sason and Sason-Kozluk roads, the area is inaccessable by motor vehicles. Numerous trails are present in the mountainous areas.

II. GENERAL GEOLOGIC SETTING

A. Geology of Turkey

Turkey is subdivided into four major tectonic regions. These include the Pontids in the northern portions of the country, the Anatolids in the central part, the Taurids in the southern and the Borderfolds in the southeastern portion.

The well known Tethian mobile belt of Europe and Asia has representatives in the Pontids and Taurids. These two major orogenic zones in Turkey, the Pontids on the north and the Taurids in the south, are separated by the west central Anatolian crystalline massifs which constitute the Anatolids. These correspond to a past geosynclinal couple on each side of the hinterland. The couple borders the Baltic Shield on the north and the African-Arabian Shield on the south. The northern shelf zone is outside of Turkey and extends from Rumania to the Caspian sea. Part of the Arabian Shield and the southern shelf zone occurs in the southeastern part of Turkey and constitutes the Borderfolds.

The Pontids are the eastern extension of the Alps and the Carpathian mountains. The Taurids are the continuation of the Dinarids. The two fold systems meet in eastern Anatolia and separate again to continue as the Caucasus and Elburz mountain systems in the north and as the Zagros system of south Iran. Several transverse fold systems occur between or at the edge of the Anatolid crystalline massifs.

The earliest diastrophic movement date back to Silurian time in the Pontids. Several successive orogenic phases affected the Pontids. These include major Permian, Jurassic and Oligocene phases.

The first major orogenic movement which influenced the Anatolids.

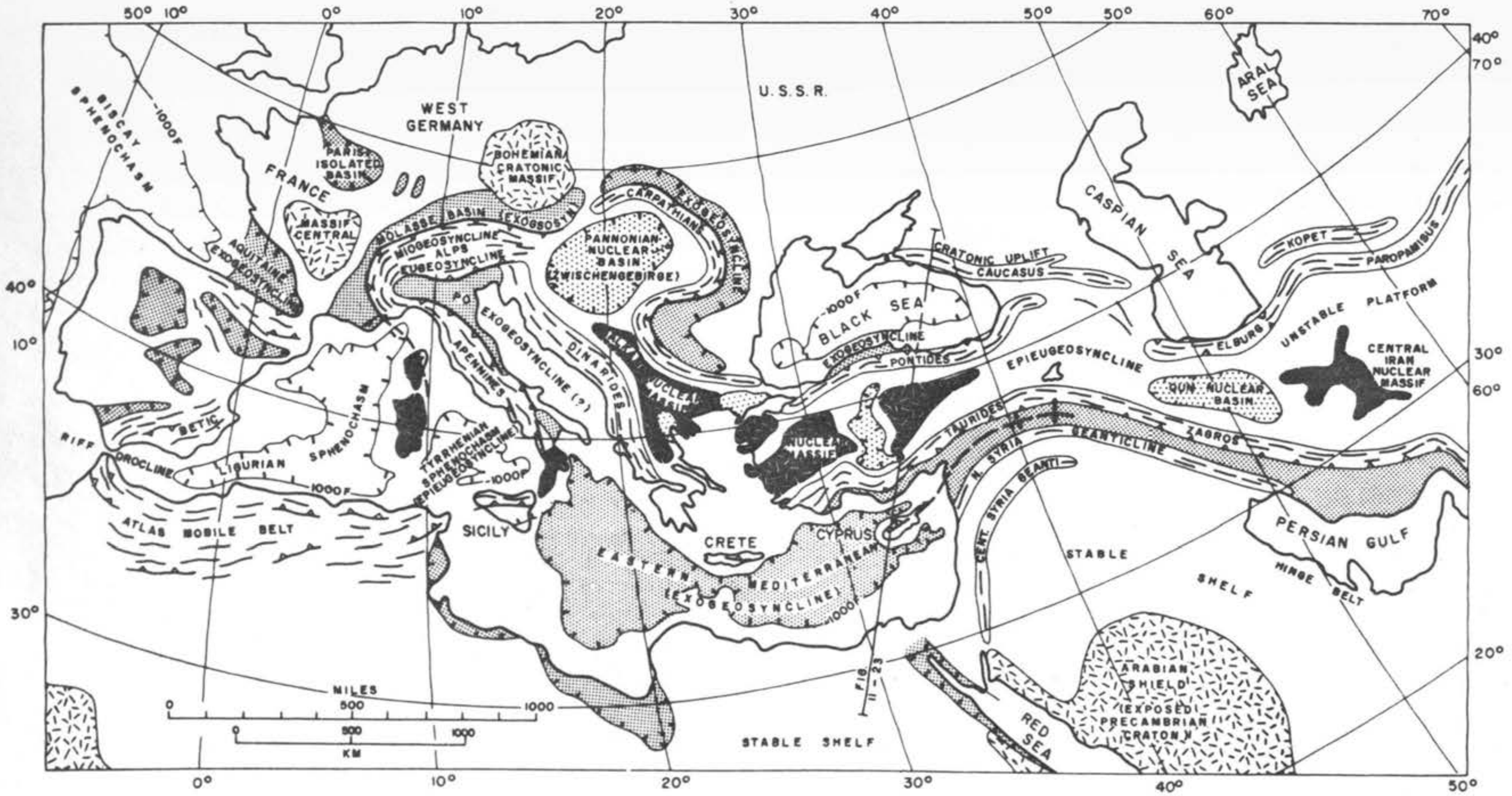

Figure 2. Tectonic map of the Mediterranean and adjoining regions (Badgley, 1965).

and Taurids are related to Mesozoic early Alpine diastrophism. A strong Upper Cretaceous-Paleocene orogeny is recorded both in the Anatolids and Taurids. The last major diastrophic phase in the Anatolids occurred at the end of Eocene, Oligocene in the Taurids, and Miocene in the Borderfolds.

The beginning of Permian, Triassic, Upper Cretaceous and Eocene times are marked by major transgressions in Anatolia. Geosynclinal conditions, characterized by submarine volcanic activity and thick flysch accumulations, prevailed throughout Turkey during Late Cretaceous except in the western Taurids and Borderfolds. A thick sequence of Paleozoic-Mesozoic carbonates are present in the western Taurids. Geosynclinal conditions lingered until Eocene locally. This research indicates that geosynclinal conditions existed until the end of Miocene in the Foothills Belt of southeast Turkey.

Uplift started at the end of Eocene in the Pontids and gradually affected the southern areas. The Borderfolds was the latest to develop. During Oligocene and Miocene intraalpine (epeieugeosyncline) basins developed and wildflysch type sediments were deposited in the Thrace and Adana regions. In central Anatolia evaporite sequences were deposited in continental basins. By the end of Miocene orogenic movements were replaced by epeiorogenic movements.

The Late Tertiary and Quaternary epochs were marked by widespread volcanism and deposition on continental platforms.

Metamorphism occurred during Lower Paleozoic and Cretaceous times in the Pontids. In both the Taurids and Anatolids metamorphic rocks ranging in age from Paleozoic to Mesozoic are present. Lower Paleozoic, Jurassic and Eocene times marked plutonic emplacement stages in the

Pontids, and Cretaceous in the Anatolids and Taurids. Submarine volcanism was active in the early Paleozoic and from Lower Cretaceous to Miocene in the Pontids, during Paleocene-Eocene in the Anatolids, and Cretaceous in the Taurids. Metamorphism, igneous activity and submarine volcanism are absent in the Borderfolds Region.

B. Summary of the geology of southeast Turkey

Southeast Turkey covers part of the Borderfolds, the Foothills, and the Taurids orogenic belt (figure 3). The Borderfolds lies at the outer northerly margins of the Arabian shield and between its craton and peripheral northern geosyncline. Gradual change from stable shelf zone into an unstable shelf area is suggested by the gradual increase in the intensity and frequence of recorded diastrophic phases and change in the tectono-environments. This transitional zone is very narrow in the west where the Arabian Shield protrudes as a wedge to the north. However, on the east a deeply subsiding basin existed throughout Paleozoic, Mesozoic, and Tertiary times. Only a thin sedimentary veneer covers the Arabian Shield west of Diyarbakir. A thick sequence of shallow marine sediments, ranging from Cambrian to Pliocene age and reflecting unstable shelf conditions was deposited east of Diyarbakir.

The Hazro uplift is northeast of Diyarbakir and west of the studied area. This uplift probably represents the surface outcrop of a hinge zone which separates the unstable shelf from the northern eugeosynclinal troughs. Somewhat meagre evidence suggests that eugeosynclinal conditions prevailed in these northern troughs during Paleozoic and early Mesozoic times. The most important eugeosynclinal phase occurred during Late Cretaceous-Paleocene times after the quiet Lower-Middle Cretaceous. Eocene time represented another quiet period.

Post-tectonic marine basins are believed to have been present in the north while transitional continental basins existed south of the hinge line. The results of this investigation indicate that eugeosynclinal conditions were established in the eastern Foothills after Eocene, and lasted until the end of Miocene.

Major diastrophism took place at the end of Miocene. This tectonism caused southward thrusting of eugeosynclinal sediments onto the stable shelf deposits of Tertiary age. The metamorphic rocks and crystalline limestones of the Bitlis Massif further north were also involved in the tectonism and thrust over the allochthonous eugeosynclinal sediments. The Bitlis Massif constitutes a nucleus of the Taurids in eastern Turkey. It covers an extensive area from Lake Van to the north of Diyarbakir, where it plunges under Cretaceous sediments to reappear as the Puturge Massif in the west.

Geosynclinal conditions were also present on the northern side of the Bitlis massif during Late Cretaceous and Paleocene times. Northward thrusting in the vicinity of Lake Van is reported by TERNEK (1953).

In summary, the geologic setting of southeast Turkey may be divided into four tectonic units from north to south; 1) the metamorphic Bitlis Massif, 2) the eugeosynclinal zone, 3) the hinge belt, and 4) the unstable shelf.

III. PREVIOUS WORK

The different structural models proposed to fit the thrust belt may be grouped under lateral and vertical tectonic hyphotheses. The supporters of the lateral compressional tectonism describe the structure in two different ways; 1) as a recumbent fold of crystalline rocks and eugeosynclinal sediments similar to the Alpine belt, of 2) as a complex pile of imbricate thrust slices. The supporters of vertical tectonism accept the latter model, but they maintain that the eugeosynclinal sediments glided along gently inclined planes under the influence of gravity and formed a chaotic assemblage of allochthonous geosynclinal sediments and basic igneous rocks resting on autochthonous Tertiary sediments.

It is generally accepted that the age of the orogenic series is Upper Cretaceous-Paleocene. By Eocene time eugeosynclinal conditions ceased to exist. Major diastrophism occurred at the end of Miocene.

The first geologic study of southeast Turkey was by OSWALD (1906). Since 1929 several authors and staff of mineral or oil companies have been investigating this region. Early workers include W. LUCIUS (1929), C. TASMAN (1933), H. F. MOSES (1934), J. H. MAXSON (1937), E. J. FOOLEY (1938), D. B. ERICSON (1939), P. ARNI (1940), S. W. TROMP (1940), and M. BLUMENTAL (1944). These authors dealt mainly with the geology of the Borderfolds. J. H. MAXSON, P. ARNI, E. J. FOOLEY, and D. B. ERICSON briefly surveyed the thrust belt.

J. H. MAXSON (1937) studied and named the Hakkari complex which consists of a chaotic assemblage of sediments mixed with basic volcanic rocks. These eugeosynclinal sediments extend from Hakkari on the east to Maras on the west along the Foothills (figure 3). It has since been given several different names such as the mixed series, orogenic flysch, green series, and Simsim ophiolites. Difference of opinion still exists as to the age of this rock group at different localities and as to the genesis of the deposits.

P. ARNI (1939 and 1940) investigated the Basor valley around Baykan, He pointed out that the imbricate fault blocks of the metamorphic Bitlis Massif, as well as the orogenic series to the south, were thrust over the Tertiary sediments of the Anatolian-Iranian Borderfolds Region during the Oligocene-Miocene orogeny. He included the marbles and mica-schists of the Bitlis Massif and the orogenic series to the south in the Iranids which he discussed under four major divisions:

1. Paleozoic marbles and schists.
2. Fractured compact grey crystalline limestones of possible Cretaceous age.
3. Graywacke, serpentine, marl and shales of Upper Cretaceous age. He found _Globotruncana_ sp., and _Orbitoides_ sp. in these rocks, and noted, however, that Lower Cretaceous and Jurassic sediments might also be present within this series.
   He also remarked that some of the marls not bearing _Globotruncana_ might be younger than Cretaceous, and drew attention to some of the slightly metamorphozed shales and graywackes.
4. Grey marls. A group of grey marls overlying other rock types and underlying nummulitic breccias are present in the

vicinity of Destumi. Other grey marls and conglomerates around Kahina village under Eocene limestones are also related to nummulitic breccias and sandy limestones in the same locality. *Nummulites* sp. occur withih these grey and red marls group in the vicinity of Kiman and south of Destumi.

He concluded that a thick imbricate slice of what he called the Destumi (Eocene) series might be present in this region, and remarked further detailed work was necessary to determine the relation of "(Eocene) grey marls" to *Globotruncana*- bearing Upper Cretaceous marls.

In addition to the above rock types, ARNI (1939) described thick nummulitic limestones within the allochthonous sediments. He suggested that these Eocene limestones were thrust slices within older rocks. ARNI also reported that, south of Minar, limestones and breccias of the thrust plate contained *Miogypsina* sp., and *Lepidocyclina* sp. along with *Nummulites* sp. He concluded that the age of these limestones were Miocene and *Nummulites* was reworked. The stratigraphy and structure of the area was too complicated, however, to allow detailed interpretation for such a brief survey.

ORTYNSKI and TROMP (1942 and 1946) studied the area near Sirvan and Minar. They disagreed with ARNI's interpretation that the serpentines, graywackes, marls and Lower Tertiary flysch and Eocene limestones constituted a complex nappe of imbricate slices. They postulated that these series constituted para-autochthonous (defined as a block displaced a short distance) material broken by unconformities.

F. BAYKAL (1949) studied the geology of Kulp and Cotela area and observed that the metamorphic Bitlis Massif, which corresponded to an uplift, was thrust southward onto the Paleocene flysch.

N. TOLUN (1949, 1953, and 1960), during his early studies, depicted the Sason-Kozluk area as a reverse block faulted region. In a north to south cross section through Sason TOLUN showed the metamorphic basement, which underlies Upper Cretaceous-Miocene sediments, as broken by several north dipping reverse faults and brought to the surface as blocks. He later studied (1953) an area south of Lake Van and recognized that the metamorphic rocks and crystalline limestones of the Bitlis Massif were thrust southward over the orogenic flysch series. These in turn were thrust over Tertiary sediments of the southern foredeep. The fossils; fusulinids (Stafella, Schwagerina, Gribrogenerina, Polydiexodina), algae (Mizzia, Gimnocodium), and brachiopods occur within the crystalline limestones which overlie the metamorphic rocks of the Bitlis Massif. He regarded these limestones as of Permian age. He also concluded that an angular unconformity existed between the metamorphic rocks and the overlying crystalline limestones. He observed that metamorphism was gradational outward from a core in the Bitlis Massif.

TOLUN (1960) described Globotruncana linnei, Globigerina, Gumbellina, Globorotalia, Textularia, lagenids, and miliolids within the allochthonous orogenic flysch series of the Baykan area. These indicate an Upper Cretaceous-Paleocene age. Within the same series, in limestones and marls, Nummulites, Orbitoides, Cyclolites were also noted. He concluded that sedimentation continued until the beginning of Eocene time. The nummulitic shallow marine limestones supposedly represent the final stage of regression. According to TOLUN (1960) these overlie all other rock types in this region. His summary of the geologic history of the area is as follows:

1. Folding and metamorphism of Paleozoic sediments before Hercynian orogeny.

2. Permian transgression.

3. Folding and uplift during the Hercynian orogeny.

4. Local submergence of Bitlis Massif and developement of geosynclinal troughs to the south during Upper Cretaceous and Paleocene.

5. Regression of seas in Eocene and uplift in Oligocene.

6. Orogeny at the end of Miocene resulting in southward thrusting in the area.

Z. TERNEK (1953) also studied the area south of Lake Van. He stated that the Bitlis Massif is thrust northward as well as southward onto the Upper Cretaceous-Paleocene orogenic series. He also concluded that imbricate thrust slices exist on the Massif.

P. G. TEMPLE and L. J. PERRY (1962) mainly describe the oil possibilities of the Borderfolds and briefly discuss the Foothills. They suggest that the ophiolite suite of submarine volcanic rocks intermixed with siliceous rocks, marls and radiolarites was tectonically emplaced within Cretaceous clastics. They interpret the structure of the thrust belt around Melefan as a recumbent fold and a nappe of Permo-Jurassic carbonates and Cretaceous ophiolites. The whole nappe structure rests on Tertiary sediments. They maintain that Cretaceous rocks which underlie the autochthonous Tertiary sediments should also include a wedge of tectonically emplaced ophiolites and that Cretaceous sediments of the upper thrust plate must have been deposited far to the north, with the material being derived from Pre-Cretaceous uplifts.

M. RIGO DE RIGHI and A. CORTESINI (1964) present the results of their studies together with surface and subsurface information acquired by Gulf Oil Company. The paper describes the geology of the western part of southeast Turkey with special emphasis on gravity tectonics in the Foothills Belt. They divide the area into three tectonic units; Taurids, Foothills, and the southern Foreland and describe the geology of each unit separately.

The chaotic assemblage of Cretaceous eugeosynclinal sediments and basic igneous rocks which overlie autochthonous shelf type deposits of the same age are in turn overlain by neoautochthonous sediments of Tertiary age. These are interpreted as having formed by gravity sliding. Age equivalence, contrasting tectono-environmental and structural aspects of the ophiolite complex and underlying shelf sediments are cited as evidence. The authors maintain that during Mesozoic time a eugeosynclinal type basin formed to the north. Here accumulating sediments glided southward into the foredeep as a result of the uplift of the hinterland.

These authors divide the gravity slide complex into three stratigraphic units; 1) the Perdeso unit of marls, shales and siliceous rocks, 2) the Cermik unit of basic igneous rocks, and 3) the Hezan unit of limestones and marls. The Perdeso unit is supposed to have been deposited in the axial portion of the geosyncline, the Cermik unit on the inner rim and the Hezan unit in the outer rim.

The authors differentiated two structural type of gravity nappes; 1) the Besni Olistrostrome type caused by submarine free gliding of a shaly incompetent series on an orogenic slope, 2) the Kevan gravity nappe type emplaced under subaerial conditions which required steeper dips and intense tangential stress. Sediments underlying the olistrostrome type are not disturbed and hence have a higher oil potential than the highly deformed sediments underlying the Kevan gravity nappe type allochthonous material.

The authors state that a regional regression representing the end of the Upper Cretaceous-Paleocene sedimentation was followed by a regional transgression of the quiet Eocene time. During Oligocene time orogenic activity was initiated and in Miocene time the foothills belt was represented by a geanticline. Silvan reef limestones were deposited on this and other structural highs in southeast Turkey. This structural uplift divided the northern intradeep (epeieugeosyncline) from the southern Foreland basin (exógeosyncline). Lice graywackes and shales were deposited in the northern intradeep and the evaporites and red beds of Germik and Selmo formations were deposited in the southern Foreland basin. They maintain that a similar gravity slide nappe formed during Late Miocene orogenesis and that the metamorphic rocks, flysch and limestones of the Taurid-Anatolid facies were displaced southward. They state that the structural characteristics of the tectonic line which extend from Maras to Hakkari is more typical of a regional gravity gliding surface rather than a thrust front since the surface of contact is nearly horizontal and the underlying Miocene sediments are not distrubed.

I. E. ALTINLI (1966) studied the geology of eastern and southeastern Anatolia extensively. He later compiled the 1:500 000 geologic map of this region, recognizing three major tectonic elements; 1) the massifs which consist of metamorphosed sediments of the Caledonian and Variscan geosynclines, 2) the orthotectonic (eugeosynclinal) region including the Taurids, Anatolids, and Iranids, and the flysch zone of the thrust front range, 3) the paratectonic (miogeosynclinal) region of southeastern Anatolia. According to him the orthotectonic region was the site of eugeosynclinal type basins with magmatism accompanying sedimentation. Upper Cretaceous-Paleocene times represented the latest and most prominent stage of eugeosynclinal type depositon. The paratectonic region was the site of miogeosynclinal type basins where sedimentation was more or less continous without accompanying magmatism. Several diastrophic phases of Mesozoic and Tertiary age affected the orthotectonic region strongly while deformation was mild in the paratectonic zone.

During ALTINLI's (1953) earlier studies of the Hakkari Massif he suggested that the orogenic sediments which extend from Hakkari to Maras might be younger than Eocene. Later, based on additional information he concluded that the orogenic flysch sequence, which constitutes an important facies throughout the thrust front from Hakkari to Ergani in the west is of Upper Cretaceous-Paleocene age. Nevertheless, among the fossils reported by different authors, and which ALTINLI records in his publication, are Discocyclina, Globorotalia (G. crassata, G. truncanoides, G. velascoensis), Heterostegina, Amphistegina, Nummulites, Nonion and belemnids. These are more characteristic of Eocene and Miocene times than Upper Cretaceous and Paleocene. ALTINLI states that during Eocene time platform conditions prevailed in the paratectonic zone while flysch-type sediments without magmatic components accumulated in the Taurids zone. Oligocene is generally represented by lagoonal type deposition followed by uplift. The Miocene transgression resulted in molasse type shallow marine deposition in post-tectonic type basins in the orthotectonic zone.

He also describes extensive Alpine-type thrusting at the Sason locality during the Late Miocene orogeny.

E. ILHAN (1964) studied the Kozluk break in front of the thrusts in the Kozluk and Melefan area and concluded that it was a chevron-type anticline broken by a fault through the axial portion. He also suggests that a major nappe of Permian limestones and Cretaceous orogenic flysch occurs in the Sason-Kozluk area. He maintains that the flysch complex underlying the Permian limestones and overlying the autochthonous Tertiary rocks was deposited on Permian limestones on the Bitlis Massif and brought to its present position by overturning and southward displacement accompanied by minor scale gravity sliding. He believes that the partly chaotic assemblage resulted from frictional grinding and mixing during the emplacement of the nappe.

In another paper ILHAN (1970) discusses the geologic significance, distribution and age of what he calls the green rocks suite of Anatolia. He concluded that all the serpentine-bearing ophiolitic complexes of Anatolia were formed during Cretaceous time and disagreed with the few geologists who reported that the green rocks in some localities might be younger than Cretaceous. He concluded that tectonic mixing with younger sediments must have misled these workers.

O. YILMAZ (1971) dealt mainly with the petrography of the Bitlis Massif north of Cacas and established that the Bitlis Massif consists of a basement of high grade metamorphic rocks and granites and a cover of low grade metamorpic rocks. Based on radioactive methods he determined the age of metamorphism of the basement and the cover of the Bitlis Massif as;

1. High grade metamorphic rocks;

   427 ± 54 million years (for ortholeptynites)

   505 ± 37 and 596 ± 88 million years (for paragneiss and mica-schists)

   325 ± 3 million years (igneous intrusions)

2. Low grade metamorphic rocks of the cover;

   97 ± 8 and 120 ± 10 million years (chlorite-mica schists)

The first stage of metamorphism apparently took place in early Paleozoic with later igneous intrusion. The second stage of metamoprhism occurred in Lower Cretaceous.

YILMAZ also detected a third stage of slight metamorphism which occurred during Eocene time. Biotite formed during this last phase had an absolute age of 47 million years.

YILMAZ noted that the original sediments and basic igneous rocks of the cover metamorphic rocks were deposited in eugeosynclinal transverse basins on the Bitlis Massif. He concludes that at the end of Miocene the Bitlis Massif was displaced onto the flysch as three superposed nappes.

In addition to published reports on the region a large amount of unpublished geologic information is available. Important results of the geologic investigations carried out by the Turkish Petroleum

Corporation are briefly noted below.

O. OZDEMIR and H. OKTAY (1968) studied the cores and logs of the five boreholes drilled at the Gemik, Bolukkonak, Alicli, Yazpinar and Meselik localities (figure 13) to test the thickness of allochthonous cover on Tertiary sediments. They suggest that semi-allochthonous (moved by the overriding thrust plate) Miocene Lice formation forms the thrust plate at Gemik, Bolukkonak, Yazpinar and Meselik localities. They conclude that different lithologic groups of Lice formation correspond to different tectono-environmental positions within the Lice basin. These were thrust southward as semi-allochthonous imbricate thrust slices during the southward displacement of the allochthonous block of metamorphic rocks, crystalline limestones and Upper Cretaceous ophiolites. They maintain that though no magmatic activity accompanied sedimentation the Lice basin was nevertheless a deep eugeosynclinal type basin. Upper Cretaceous and Eocene fossils in the cores are regarded as reworked since characteristic Miocene fauna were also detected in some units along with Eocene and Upper Cretaceous-Paleocene fossils.

O. SALTIK and A. GOKTEPELI (1969) mapped the area in reconnaissance fashion and measured a stratigraphic section of the Miocene Lice formation south of Cacas. They report characteristic Miocene fossils such as Miogypsina within the graywackes and shales of the Lice formation.

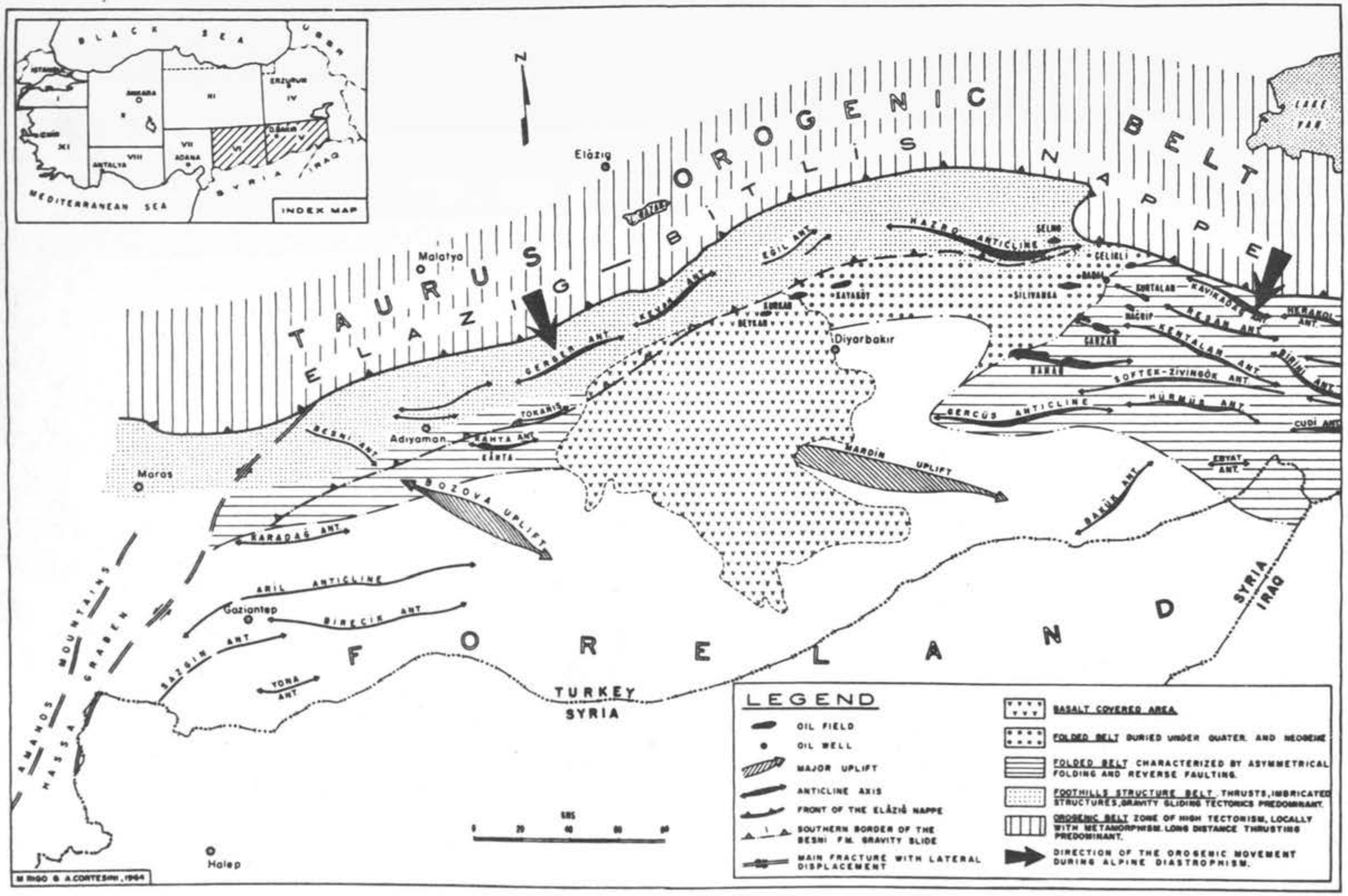

Figure 3. Schematic structural map of southeast Turkey (M. de Righi and A. Cortesini, 1964).

IV. STRATIGRAPHY

A. Summary of the stratigraphy of southeast Turkey

At Derik in southeast Turkey a thick Precambrian accumulation of clastics and volcanic rocks known as the Derik formation, 2000 meters thick, (thicknesses given are approximate) underlies Cambro-Ordovician rocks. The latter comprises an extensive uniform clastic sequence with intervening limestones and dolomites. These systems consist of the Sadan red clastics, Sosink dolomite, sandstone and siltstone group, and Bedinan shales with a total thickness of over 3000 meters.

The Silurian and Devonian systems are not well developed in southeast Turkey. The Bedinan shales grade upward into silty, sandy Handof shales, 900 meters thick, in the Mardin area (figure 3). At the Hazro uplift to the north Devonian shales with sandstone and limestone intercalations are up to 400 meters thick.

Partly reef limestones of the Imbirik formation, 200-300 meters thick, and underlying Hazro basal clastics, 100-200 meters thick, of Permian age transgressively overlie the Lower Paleozoic rocks (figure 4). These carbonates thicken to the west. The Imbirik formation is in turn overlain by the shallow marine evaporite, red bed and limestones of the Aril formation, 1000 meters thick, of Triassic-Jurassic age. Beduh shales and sandstones, 150 meters thick, of the same age occur to the north of Hazro uplift. Triassic-Jurassic formations are overlain by the Mardin carbonates, 500 meters thick, of Lower-Middle Cretaceous age. This formation is well developed and widespread in southeast Turkey. It represents a quiet period of shallow seas.

Karabogaz marls and limestones and Kastel clastics, 200-300 meters

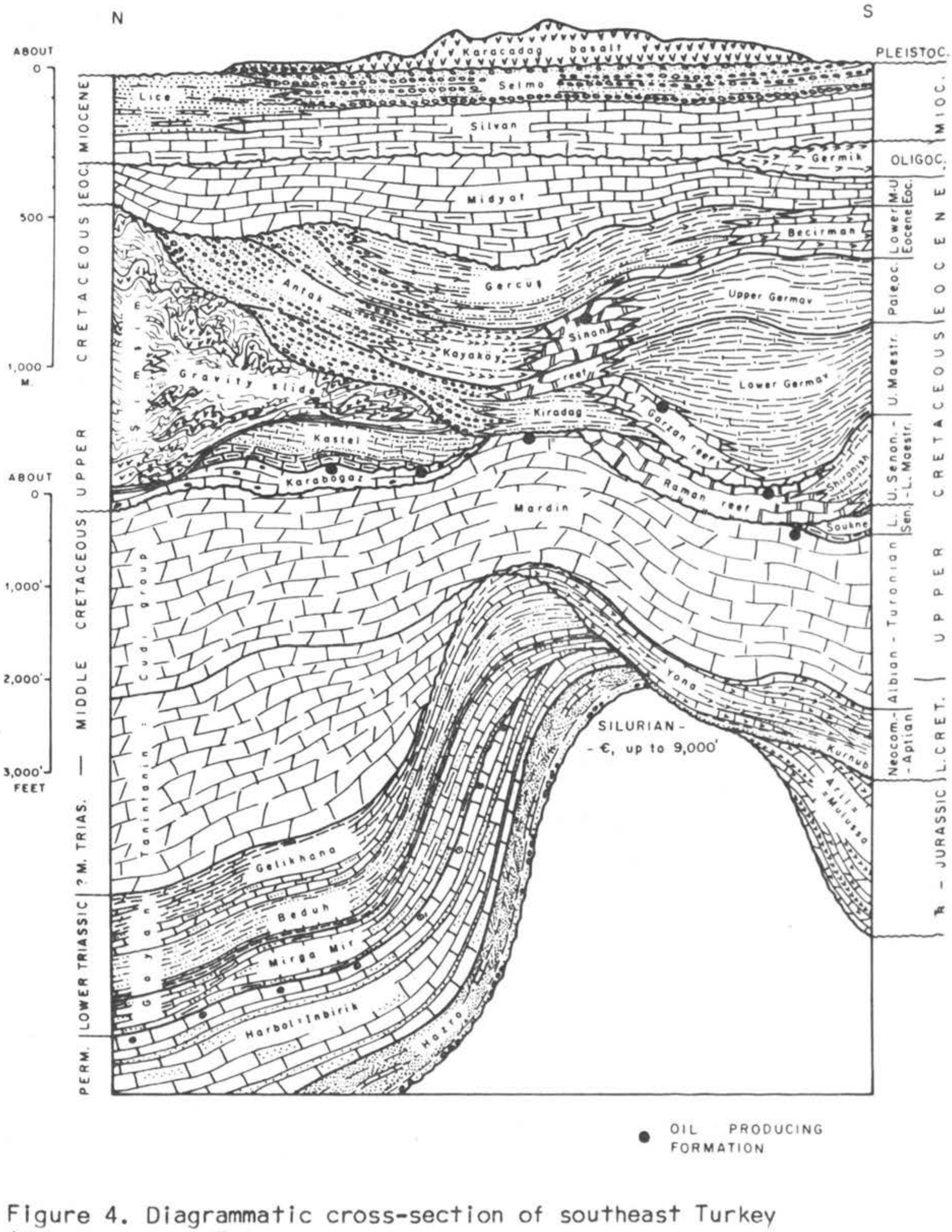

Figure 4. Diagrammatic cross-section of southeast Turkey (D. Rigassi, 1971).

thick, overlie the Mardin carbonates north and northwest of Hazro uplift. These are of Upper Cretaceous age and are equivalent to the Raman reef carbonates and Kiradag shales, 100-200 meters thick, of the southern areas. Ophiolitic mixture of geosynclinal sediments and basic igneous rocks of varying thickness cover the Kastel formation to the north. These are in turn overlain by the red clastics of Paleocene-Lower Eocene age called the Antak formation, 1000-1500 meters thick. In the south, the Raman reefs are overlain by Germav shales of Paleocene age, 500-1000 meters thick. Sinan and Garzan reef limestones occur as lenses within Germav formation. These reefs were formed on local structural highs during Paleocene time. Germav shales are overlain by Gercus red clastics and marls, 200-300 meters thick, of Lower Eocene age in the south. Both the northern Antak and southern Gercus clastics are overlain by neritic Midyat limestones, 200-300 meters thick. Similar to Mardin carbonates, the Midyat limestones also represents a quiet period of widespread shallow seas in southeast Turkey.

Germik evaporites and Selmo red sandstones, 300-400 meters thick, of Oligocene to Miocene age overlie the Midyat limestones with local unconformities. These transitional continental formations of the southern foreland are time equivalent of the marls, shales and graywackes of the Lice group. Silvan reefs were formed on local structural highs and on the hinge zone between the southern Selmo and northern Lice basins. The Selmo formation is overlain locally unconformably by the continental Lahti clastics, 500 meters thick, of Pliocene to Pleistocene age. A similar clastic sequence comformably overlies the Lice group to the north.

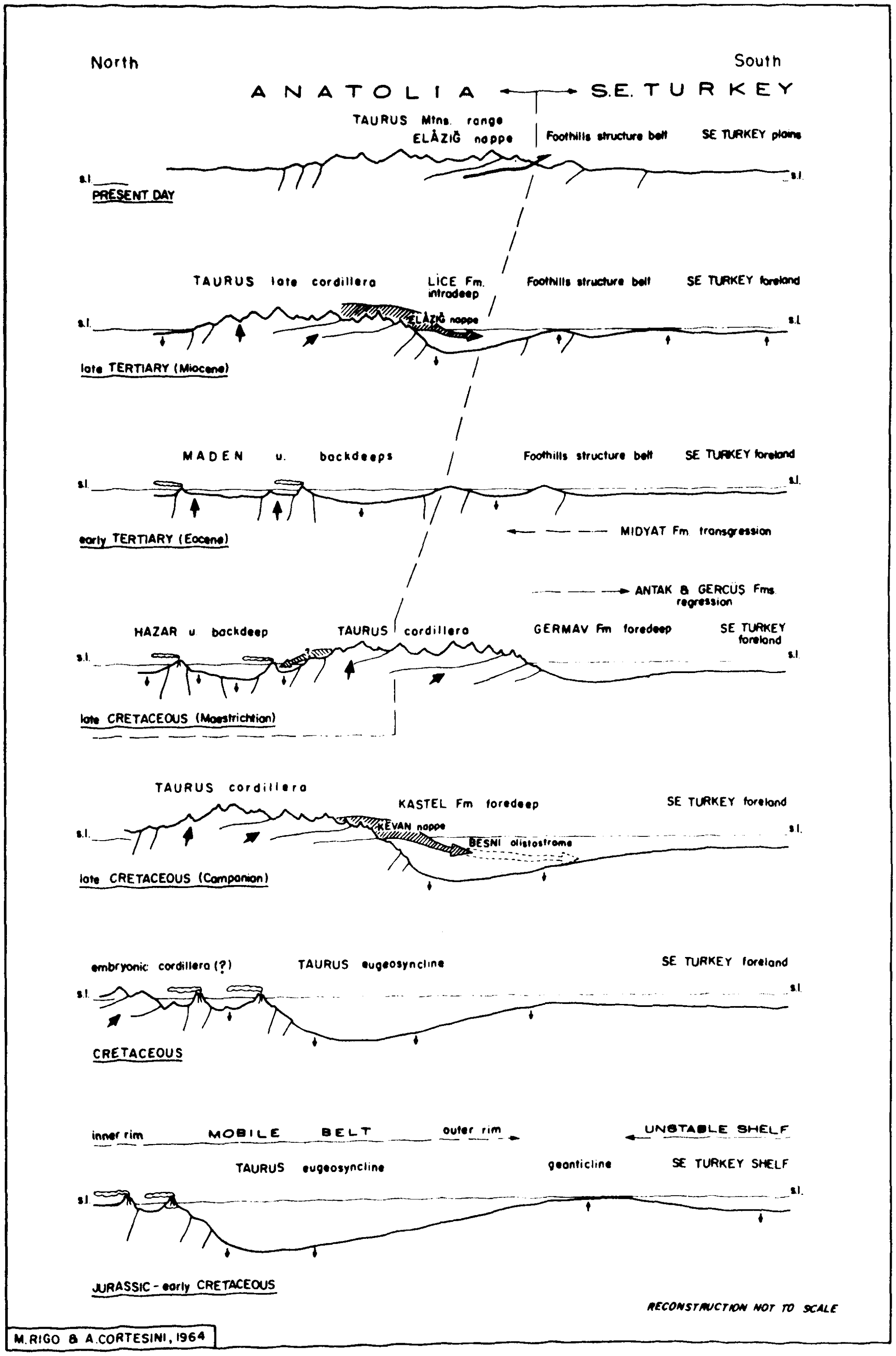

Figure 5. Schematic evolution of Tauris eugeosyncline and the southeast Turkey marginal basin (M. de Righi and A. Cortesini, 1964).

Figure 5 summarizes the evolution of the northern Taurus geosyncline and the southeast Turkey basin according to RIGHI and CORTESINI (1964).

B. Stratigraphy of the Sason-Baykan area

A group of allochthonous low grade metamorphic rocks, massive limestones, geosynclinal sediments and autochthonous marginal basin-type deposits constitute the stratigraphy of the Sason-Baykan area.

Unstable shelf conditions prevailed in the Borderfolds and Foothills in front of the Bitlis Massif during Late Cretaceous-Paleocene times while backdeep type basins existed in the north where eugeosynclinal sediments were deposited. During the Eocene a brief period of stable shelf conditions prevailed throughout the area. Midyat shallow marine blanket biomicrites were deposited both in the southern Borderfolds and norhtern geosynclinal area. Stable shelf conditions were replaced by geosynclinal conditions again in Oligocene-Miocene times in the Foothills after a possible major uplift in the north. This uplift resulted in regression of seas from backdeeps, and most probably followed a diastrophic pulse and thrusting. A transitional continental basin existed in the southern Borderfolds Region while a rapidly subsiding eugeosynclinal trough occupied the frontal portion of the Bitlis Massif.

A westnorthwest trending hinge on the extension of the Hazro uplift separated the two basins. Sason-Baykan flysch and marl series accumulated in the inner rim and axial portion of the frontal geosyncline with accompanying basic igneous rocks. Lice calcareous graywackes, shales and marls with subordinate basic igneous rocks were deposited on the outer flank of the same trough. Germik-Selmo evaporites and red sandstones were deposited on the southern transitional continental basin.

Silvan reef limestones and lower Selmo salts were deposited in the hinge belt.

The metamorphic rocks, crystalline limestones, and backdeep sediments were thrust as a massive block over the southern eugeosynclinal Sason-Baykan sediments during the Late Miocene orogeny. The latter was thrust over the Lice outer flank sediments, which was in turn thrust over the Selmo-Germik marginal basin deposits further south.

Molasse-type Lahti clastics were deposited over Selmo formation in the south and the Firki clastics over the Lice group to the north in post-tectonic basins during Pliocene-Pleistocene times.

The stratigraphy of the Sason-Baykan area is described under three major groups; 1) the allochthonous massif of the metamorphic rocks, limestones, and backdeep sediments, 2) the autochthonous Tertiary sediments of the southern marginal basin, and 3) the allochthonous geosynclinal sediments of the Lice-Baykan frontal trough.

1. Allochthonous massif

Paleozoic gneisses, amphibolites and granites are reported to constitute the core of the Bitlis Massif (YILMAZ, 1971), north of the mapped area. A series of Cretaceous low-grade metamorphic rocks and massive crystalline limestones cover the core.

The metamorphic rocks and limestones of the Bitlis Massif are thrust as a thick massive block onto the frontal trough sediments in the Sason and Kozluk area (plates 1 and 2). A tectonic slice of non-metamorphic sediments occurs within this allochthonous block. The massive limestones are supposed to be of Permian age (TOLUN, 1960). However, field observations strongly suggest a younger age. The included non-metamorphic sediments are believed to be of Upper Cretaceous to Eocene age. The general sequence from base upward within the allochthonous block is as follows; quartzite-chlorite schist group, calc-schist-crystalline limestone group, non metamorphic sediments, and calc-schist-crystalline limestone group.

a. Metamorphic rocks

Dark foliated green schists, massive quartzites, and calc-schists, 600-700 meters thick, of Cretaceous age constitute the metamorphic rocks of the allochthonous block. These correspond to the cover rocks of the Bitlis Massif (YILMAZ, 1971), and are derived from metamorphism of eu-geosynclinal type sediments. High-grade metamorphic rocks were not encountered in the thrust block (plate 1 and 2).

Greenschists are characterized by conspicuous foliation and variable composition. Quartzites occur as massive non-foliated rocks with a typical display of different colors. Calc-schists are buff-colored and foliated (figure 7). Foliation is due to the uniform orientation of flaky minerals. Chlorite, quartz, feldspar, muscovite, talc, chloritoid, actinolite, and pistacite are the main minerals of greenschists. Interlocked grains of quartz and subordinate micas, feldspars, hematite and apatite constitute the quartzites. Calc-schists consist mainly of calcite, sericite, and chlorite with subordinate talc, epidote, sphene, feldspar and actinolite (YILMAZ,1971).

The observed sequence upward is greenschists, quartzites, and calc-schists. Quartzites and greenschists are closely associated and are gradational and intertonguing. It is not always possible to separate the two. Calc-schists are more closely associated with massive limestones which they underlie. Extensive crystalline limestone lenses or layers occur within the calc-schists around Goderin tepe (Turkish word meaning hill) and the Musritan region (plates 1 and 2).

The intercalated nature of the two units is also observable on the western slopes of Halkis Mountain (plate 2). Lenses or layers of limestones also occur within quartzite-greenschist group. Chert layers within and at the base of massive limestones have been recrystallized to quartzite.

The reported thickness of Cretaceous metamorphic rocks is over 700 meters. Quartzites and greenschists constitute the bulk of metamorphic rocks. Calc-schists are generally thin, although, at Goderin tepe and Kuringis (plate 2) they attain more than 200-300 meters thickness. The metamorphic rocks gradually thin out eastward away from the Sason, Gemik, and Musritan area. North of Melefan mainly massive limestones constitutes the allochthonous block (plate 4).

Until the recent investigation of YILMAZ (1971), it was generally accepted that the metamorphic rocks of the Bitlis Massif were of Paleozoic age (TOLUN, 1960). The degree of metamorphism was thought to decrease gradually outward from the inner portions of the massif. Gneisses and amphibolites of the katazone were supposed to grade into mica- and chlorite schists of the mesozone and then into a quartzite-calc-schist group of the epizone. Based on the radioactive age determination of minerals. YILMAZ disclosed that the age of metamorphism for the greenschist-quartizte-calc-schist suite is Lower Cretaceous. This series of younger metamorphic rocks covers the Paleozoic basement of the Bitlis Massif. The latter consists of gneisses, amphibolites and granites. Metamorphism is not gradational outward from an inner katazonal core.

The greenschists developed from basic igneous rocks and marls while argillaceous feldspathic or ferruginous sandstones constituted the original sediments of the quartzites (YILMAZ, 1971). The original rock types suggest eugeosynclinal deposition with accompanying basic igneous activity. Black shales, considered typical of such deposits, crop out at several localities in slighly sericitized form as a rock type of the greenschist group.

b. Massive limestone and dolomite group

The metamorphic rocks of the Bitlis Massif are overlain by a thick mass of partly dolomitic and crystalline limestones (TOLUN, 1960). The reported age is Permian (TOLUN, 1960). This grey massive dolomitic limestone group, 300-400 meters thick, also constitutes the uppermost unit of the allochthonous block in the Sason-Melefan area (plate 2). These limestones grade into non-metamorphic backdeep sediments. This relationship suggests that Cretaceous limestones also forms a part, if not all, of the group.

The massive limestone and dolomite group of the allochthonous block is easily recognized by its color, intense jointing, absence of bedding, presence of calcite veins and associated rough karst topography, and high peaks (figures 6 and 8).

The group is dolomitic in the middle and upper portions. The lower parts are less uniform. Sandy and clayey limestones alternate with pure varieties. Recrystallized chert layers occur at the base and within the lower portion. Degree of crystallinity varies from white marble with interlocking coarse calcite crystals to microcrystalline varieties.

Figure 6. Crystalline limestones of the allochthonous block, Halkis Mountain, south of Sason, looking south.

Figure 7. Calc-schists of the allochthonous block, east of Musritan. f. Fault.

No fossils have been observed within this group. Three conspicuous joint sets are developed with the prominent set horizontal. Tectonic breccia occurs along thrust contacts.

The crystalline limestone and dolomite group, which overlies the metamorphic rocks, constitutes a thick continuous mass extending from west of Sason to the east of Baykan on the upper thrust block. Its greatest thickness is northeast of Sason where it is over 1000 meters thick. The thickness decreases rapidly towards the south. On the frontal portions of the allochthonous block the crystalline limestones are not more than 50 meters thick. Massive crystalline limestones occur only as isolated patches on metamorphic rocks northwest of Sason.

Crystalline limestone interbeds within metamorphic rocks are common. North of Binuni and Rabat around Gijik tepe and Bagnava tepe several beds of varying thickness occur within the greenschists and quartzites (plate 1). Calc-schists also include layers and lenses of crystalline limestones. The intercalated nature of the calc-schists and crystalline limestones is readily observable around Goderin tepe and Musritan, and Kuringis (plate 2). Pure, finely-crystalline limestones grade into calc-schists of uniformly oriented mica and chlorite flakes and interlocking crystals of calcite and subordinate quartz. The gradational nature of the contacts suggest that crystalline limestone layers within metamorphic rocks are original sedimentary intercalations rather than tectonic slices.

Interlayers of metamorphic rocks crop out within the main mass of the limestone-dolomite group on the southern slopes of Kalems tepe; north of Destumi (figure 14), outside of the mapped area. They are also known north of Kozluk and Permus (plates 1 and 2). The interlayers occur more frequently in the lower parts of the group. The metamorphic rocks consist mainly of calc-schists, but sericite-chlorite schists and talc schists are also present, as well as quartzites. The latter correspond to original chert layers.

On the eastern slopes of Kortalo tepe and the southern slopes of Kandil tepe (plate 1) a tectonic slice of thin bedded compact sandy limestones grades into calcareous sandstones and constitutes a member of the red marl, mudstone, black micrite, and spilite series. The included thick layers of crystalline limestone is identical in lithology to the massive limestone-dolomite group. These non-metamorphic sediments make up the tectonic slice between the underlying quartzites and overlying crystalline limestones and calc-schists.

The non-metamorphic sediments belong to the backdeep sediments of Upper Cretaceous-Paleocene age. Gradation from grey, compact, microcrystalline limestones into overlying sandy grey thin-bedded limestone-calcareous sandstone members of the backdeep sediments may be observed north of Kuringis (plate 2). The sandy grey limestones of backdeep sediments resembles the well-bedded sandy intrasparites of the Eocene-Miocene frontal trough sediments.

On the southern slopes of Seyhfethettin tepe, north of Binuni and Kevrigari tepe (plate 1), several patches of buff-colored, well-bedded partially crystalline nummulitic biomicrites rest directly on crystalline limestones. The nummulitic biomicrites are Eocene in age and are supposed to constitute the uppermost layer of the backdeep sediments. They are the equivalent of the Eocene Midyat limestones. A remnant of the same buff- colored Eocene nummulitic biomicrite is present on the grey, finely-crystalline limestones west of Kozluk. The contact between the two rock types is obscure. Although the contacts are mapped as thrusts, the red marl and mudstone series and the grey compact crystalline limestones may well be intercalated at this locality.

The age of metamorphism for samples of the low-grade metamorphic rocks is reported to be 100-120 million years and corresponds to Lower and Middle Cretaceous. The original sediments may have accumulated anytime from Paleozoic to Lower Cretaceous. It is probable that the bulk of the original sediments of the metamorphic rocks and the massive limestones were deposited in the Early Cretaceous. Regional metamorphism must have taken place during an orogenic phase at the end of Early Cretaceous. Accumulation of eugeosynclinal type sediments probably resumed in backdeep-type basins on the Bitlis Massif during Upper Cretaceous and continued until the end of Eocene. Limestones similar to the earlier deposits may have accumulated along with other rock types during this period. The crystallization of such limestone members of the Upper Cretaceous-Eocene backdeep sediments must have taken place at a much later stage, most probably during the Late Miocene orogeny, since the nummulitic limestones of this group are also locally crystallized into a coarse-grained white marble.

c. Backdeep sediments

A group of marls, graywackes, silicified rocks and limestones are present as a tectonic slice within or as an outlier on the metamorphic rocks. These sediments accumulated in geosynclinal basins on the Bitlis Massif during Upper Cretaceous to Eocene times. These early geosynclinal basins of the north are referred to as backdeeps in order to differentiate

Figure 8. Fenster of silicified serpentines and sediments (1), under overthrust crystalline limestones (2), Halkis Mountain, south of Sason, looking east.

Figure 9. An outlier of sediments on the metamorphic rocks of the thrust plate, north of Rabat, looking west. 1)Nummulitic, partially crystalline biomicrite, 2)red and blue marls, s. Sason thrust.

them from the southern Oligocene-Miocene Lice-Baykan geosynclinal basin. The backdeep sediments were thrust southward along with the metamorphic rocks at the end of Miocene.

A horizontal tectonic slice, 100-200 meters thick, of non-metamorphic sediments within the allochthonous block occurs at about the 1500 meter elevation. It is some 600 to 700 meters higher than the allochthonous geosynclinal sediments of the frontal trough (figures 58, 41 to 46). The sedimentary slice is extensive, and despite tectonic complications may be observed throughout the Sason and Kozluk area (plate 1 and 2) at the same tectono-stratigraphic position within the allochthonous block. The slice is visible 5-6 kms north of Sason.

The upper boundary of the sedimentary slice is a thrust. The lower boundary is believed to be depositional on the metamorphic rocks and crystalline limestones in a backdeep-type eugeosynclinal basin. Subsequent thrusting brought the basement rocks over these sediments.

Besides the main tectonic slice, there are scattered outliers of sediments on the metamorphic rocks to the north of Rabat and Binuni and on the southern slopes of Seyhfethetting tepe (plate 1, figure 9). It is believed that these rocks were also originally deposited on the metamorphic rocks and carried south with them during thrusting.

The main rock types of these outliers and the tectonic slice are graywackes, red and blue marls and black micrites. Grey sandy limestones, nummulitic biomicrite, red sandstone, red and grey mudstone, spilite and silicified serpentines are also present. These sediments are not distinguishable from the Sason-Baykan frontal trough sediments, which consist essentially of the same rock types. Due to tectonic disturbance it is not possible to establish a unified sequence.

East of Sason the observable sequence consists of silicified rocks, green graywackes, red marls, and sandstones (figures 9 and 27). North of Rabat a partially crystalline buff-colored nummulitic biomicrite overlies a series of red and blue marls. These occur as an outlier on metamorphic rocks.

Samples collected from the buff-colored partially crystallized biomicrites north of Rabat on the southern slopes of Seyhfethettin tepe, Kevrigari tepe, and Has tepe (plate I) contain the following fossils; _Nummulites_ sp., _Discocyclina_ sp., _Operculina_ sp., _Alveolina_ sp., _Rotalidae_ sp., and _Globorotalia_ sp. These are characteristic of an Eocene age. Samples of red and blue marls collected from an outlier north of Rabat and from a tectonic slice east of Sason contain _Globigerina_ sp., and _Globorotalia_ sp. This fossil assemblage ranges in age from Paleocene to Recent. A sample of graywackes from the southern slopes of Halkis Mountain, 3 kms north of Belav contains _Discocyclina_ sp., _Lituola_ sp., _Gaudryina_ sp., _Kathina_ sp., _Cibicides beaumontiana_, _Bulimina_ sp., _Globorotalia aragonensis_, _Globorotalia aequa_, _Globorotalia_ sp. These are characteristic of the upper Paleocene and Lower Eocene.

Abundant reworked Upper Cretaceous fossils occur in the Oligocene-Miocene Lice graywackes and the Sason-Baykan marl-flysch series. These fossils must have been derived from northern backdeep sediments. _Globotruncana stuarti_, _Globotruncana_ sp., of Upper Cretaceous age were found along with _Globigerinoides_, _Globigerina_, _Globorotalia_, _Cibicides_, _Discocyclina_, _Amphistegina_, and _Nummulites_ in the Miocene Lice graywackes in drilling in the Meselik area (figure 22). Presence of such reworked fossils, serpentines and exotic gravity slide blocks of Upper Cretaceous-Paleocene backdeep sediments misled several authors to conclude that the allochthonous geosynclinal sediments of the frontal trough were also of Upper Cretaceous-Paleocene age.

TOLUN (1960) reports several outliers of sediments on the metamorphic rocks of the Bitlis Massif. He states that buff-colored nummulitic Eocene limestones constitutes the uppermost layer of these outliers. This limestone bed overlies a 20-30 meters thick conglomerate layer which in turn overlies a series of red marls with characteristic Upper Cretaceous fossils such as *Globotruncana linnei*, *Globotruncana stuarti*, *Gumbellina* and lagenids (TOLUN, 1960). TOLUN, however, also postulates that the buff-colored nummulitic Eocene limestone constitutes the topmost layer of the frontal trough sediments, and concludes that regional regression of the seas took place at the end of Eocene.

The buff-colored nummulitic biomicrite layer constitue the topmost unit of the outlier north of Rabat (figure 9). However, field studies for this research disclosed that Eocene limestone does not constitute the uppermost layer of the front trough sediments as postulated by TOLUN (1960), and others. A thick section of Oligocene and Miocene eugeosynclinal sediments cover the key limestone horizon. Hence, even if regression took place, it was limited only to the northern backdeeps. Presence of nummulitic limestone pebbles along with other rock types within the conglomerates of the southern Oligocene-Miocene sediments indicates that uplift took place in the north after Eocene time. However, there is not enough field criteria to ascertain whether this uplift took place right after Eocene, or later.

2. Autochthonous Tertiary sequence

The autochthonous Tertiary sequence of sediments consists of the Upper Cretaceous-Eocene Antak red clastics, Middle-Upper Eocene Midyat limestone and Oligocene-Miocene Germik, Silvan and Selmo formations.

The Antak red clastics comprise a widespread Paleocene-Lower Eocene section in the Foothills which was deposited in front of a rapidly rising landmass. The Midyat limestone is a blanket type biomicrite and represent a quiet stable period of widespread shallow seas. The Germik evaporites and Selmo red sandstones were deposited in a post-Eocene transitional continental basin linked by a west-northwest trending hinge line to the northern eugeosynclinal Lice-Baykan trough. The hinge area was the site of the deposition for Silvan algal limestones and lower Selmo salts. The green graywackes and shales of the Lice group, which are partly autochthonous, were deposited on the southern rims of the northern trough (figure 36).

a. Antak formation

The Antak formation consists of thick red conglomerates, sandstones and shales with marl partings, 1000-1500 meters thick. The formation covers the Upper Cretaceous gravity slide and is overlain by Eocene Midyat limestone. The poorly sorted coarse red clastics were deposited in front of a rapidly rising landmass to the north.

The Antak formation of red clastics is the oldest exposed in the area. It crops out under the Midyat limestone in the cores of the eroded Golap and Belaso anticlines. Only the upper 200 meters is exposed at the surface (plate 3 and figure 10). These beds are predominantly red conglomerates and cross-bedded sandstones with marl intercalations and thin shale partings. Subsurface information of the

Turkish Petroleum Corporation indicates that the thickness varies from 1700 meters at the Golap drill hole in the northwest corner of the studied area to 1000 meters in the Alicli drill hole on the east (figure 22).

At the Golap drill hole the Antak formation overlies the Upper Cretaceous intraformational ophiolitic mixture of sediments and basic igneous rocks. Here the formation is dominantly sandy and conglomeratic. At the Alicli drill hole this formation overlies and intertongues with the Raman, Garzan, and Sinan reef carbonates of Upper Cretaceous to Paleocene age. Here the upper 100 meters of the formation is conglomeratic. The lower 900 meters of the section consists of red and green shales with occasional sandy and conglomeratic partings. The upper Sinan reef carbonate member is a 200 meters thick tongue in the lower parts of the clastic section, and overlies lower Sinan and Garzan reef carbonates. The latter rest unconformably on Raman reef carbonates of Upper Cretaceous age.

Fossils identified in the Turkish Petroleum cores of the Paleocene-Lower Eocene series in the vicinity of the studied area include: Rotalia, Lockhartia, Loftusia, Discocyclina, Globigerina, Globorotalia, textularids, miliolids, and radiolarids.

b. Midyat limestone

The Midyat limestone is a buff-colored 100-150 meters thick blanket-type biomicrite with included benthonic foraminifera of Eocene age, such as Nummulites. It is widespread with distinctive uniform lithology of wide areal extent (plate 3 and figure 10). The Midyat limestone is medium-to thick-bedded, highly resistant to weathering and well-jointed. The composition varies from biomicrite to biosparite, intra-

Figure 10. Antak red clastics (1), and overlying Midyat limestone (2). A view of the northern flank of the Dodan anticline, south of Baykan (units 1 and 2 of figure 30). Photo by P. D. Proctor.

Figure 11. Red and grey sandstones of the Germik and Selmo formations (2) overlying the Midyat limestone (1) on the northern flank of the Dodan anticline (unit 3 of figure 30). Baykan thrust overriding the Dodan anticline in the background, near Minar. Photo by P. D. Proctor.

sparite and algal limestone. The lower parts are frequently sparry and dolomitic. The upper parts are chalky. The average thickness is 100-150 meters within the autochthonous block in the area. It is underlain by red Antak clastics and overlain by clastics or evaporites of the Germik formation. In the Hazro distict west of the project area the Germik formation is missing and the Midyat limestone can not be differentiated from the overlying Silvan algal limestone.

Two kms south of Hamzali, upper parts of the Midyat limestone contain the following fossils: Praerhapydionina (?), Tritaxia, Archaias (?), miliolids, and ophthalmidids. Various authors report a rich fauna of Nummulites and miliolids, Operculina, Assilina, Alveolina, Discocyclina, Orthophragmina, Amphistegina, Rotalia and textularids.

The Midyat limestone represents a stable shelf period which prevailed in Middle-Upper Eocene times. The limestones were deposited in quiet shallow seas which covered both the Borderfolds and the northern geosynclinal areas. The formation is recognized as a 5-20 meter thick buff biomicrite layer of Middle-Upper Eocene age within the allochthonous geosynclinal sediments of the Sason-Baykan area.

c. Post-Eocene Germik, Silvan, and Selmo formations

The lower Germik evaporite and upper Selmo alternating red and grey clastic sequence overlies the Midyat limestone in the southern marginal basin area. The Germik evaporites are in turn overlain by Silvan reef carbonates in the hinge area to the west, as well as on other structural highs to the south. The evaporites disappear towards the northeast around Minar and Madar where the Germik-Selmo red and grey sandstones overlie the Midyat limestone directly. Westward, around Hazro, the Midyat limestone is overlain directly by Silvan reef carbonates. Selmo sandstones overlap the Silvan limestone on the southern flank of the hinge zone while green graywackes of the Lice group cover it on the northern flank. The penesaline and saline evaporites present around Melefan in the hinge area are considered a lower evaporite member of the Selmo by OZDEMIR and OKTAY (1968). All of the above formations are of Oligocene-Miocene age.

i. Germik formation. This formation consists of shales, marls, evaporites of varying thickness and red and grey sandstones. It crops out in the Golap and Belaso anticlines in the west as a 10-50 meters thick, reddish, buff, marly, shaly, evaporite between the underlying Midyat and overlying Silvan limestones (plate 3). The Germik formation does not crop out elsewhere within the research area.

Drilling data from the Turkish Petroleum Corporation indicates a 250 meters or more thickness of a marly calcareous dolomitic unit with thin shale partings and anhydrite lenses near Kozluk and Melefan. This thickness increases southward to more than 600 meters in the Selmo and Habanidere drill holes south of the thrust front. Evaporites of both the Germik formation and the lower Selmo member thin and disappear to the east around Madar and Minar where regularly alternating, medium-thin-bedded red and grey sandstones overlie Midyat carbonates (figure 11). These sandstones, which constitute the whole post-Eocene section at this locality, are identical in lithology to the upper member of Selmo formation. No known lithologic criteria exist to distinguish the Germik and Selmo formations in this area.

An unconformity is generally placed between the Midyat and Germik formations and slight unconformity does occur in the Golap and

Belaso areas. However, to the east in the Madar and Minar area south of Baykan, the red and grey sandstones overlie the Midyat carbonates comformably (figure 11).

Fossils identified by the Turkish Petroleum group from cores of the Germik formation in several drill holes in or near the studied area include Globigerinoides, Robulus, Nonion, Cibicides, Uvigerina, Eponides, Globigerina, Textularia, Amphistegina, Operculina, Elphidium, and ostracods. This fossil assemblage has an Oligocene to Miocene age range.

ii. Silvan limestone. The Silvan limestone is a reef formation which occurs on the hinge belt as well as on other structural upfolds in the south.

Locally a chalky, shaly, buff-colored, fosiliferous, medium-to thick-bedded and jointed limestone bed crops out in the Golap and Belaso anticlines (plate 3). The limestone overlies the Germik formation and is in turn overlain by sandstones and shales of the Lice group. The thickness of the limestone varies between 20 to 50 meters in this locality. No similar reef limestone bed was encountered in the Alicli drill hole within the post-Eocene section which could be correlated with the Silvan limestone. The Silvan limestone is absent in the Selmo and Habanidere boreholes south of hinge belt in front of the thrust zone. Apparently this formation is confined only to the structural upfolds where shallow marine, high-energy and low supply conditions prevailed.

The following fossils were detected from a sample 3 kms east of Herent village; Amphistegina, Elphidium, Textularia, algae, and bryozoa. These are indicative of Oligocene to Miocene age. the Silvan limestone is generally considered to be Lower Miocene.

iii. Selmo formation. This formation consists of a lower evaporite and upper clastic member. The lower member of the Selmo formation consists of calcareous shales and marls with gypsum and occasional intercalations of silty, sandy, dolomitic beds. The thickness of this member is 204 meters at the Alicli drill hole (OZDEMIR and OKTAY, 1968). The lower 94 meters of the member consists of rock salt. Shale, marls, dolomite, and gypsum constitue the upper 110 meters.

In the Alicli borehole the Germik formation underlies the rock salts of the lower Selmo where the former also has characteristics of a penesaline facies with a calcareous, dolomitic, shaly composition and anhydrite intercalations. Based on these associations it is reasonable to assume that a complete cycle of Oligocene-Miocene evaporitic deposition occurs in this locality. The Saline phase occurs only around Melefan. Elsewhere in the hinge line area and in the southern miogeosynclinal basin the saline phase is not developed.

The upper Selmo member is characterized by typical red and grey alternations of medium-bedded sandstones with shale partings and conglomerates. Sandstones are medium sorted, poorly consolidated, subangular, calcareous graywackes with arkosic and rare arenitic variations. Cross-bedding and regularly alternating red and grey colors are characteristic.

The average thickness of the Selmo formation is over 600 meters. The upper Selmo member is 176 meters thick at the Alicli borehole (OZDEMIR and OKTAY, 1968). Although no fossils were found in samples collected, the Turkish Petroleum group reports several characteristic Miocene fossils from the Selmo formation.

Figure 12. Lahti formation, south of Melefan, looking southwest.

Figure 13. Firki clastics (1) overlying Lice graywackes (2), west of Tuzluk, looking west (unit 14 of figure 24). Metamorphic thrust plate (3) in the background.

d. Pliocene-Pleistocene deposits

Continental clastics overlie both the Selmo formation in the south and the Lice group in the north. These younger sediments reach 500-600 meters thickness. The northern depositional limit parallels the thrust front and suggests that deposition is post-tectonic and took place in exogeosynclinal type basins.

i. Lahti formation. The coarse, clastic Lahti sequence, more than 500 meters thick, unconformably overlies the Selmo formation, south of Herent, Kozluk and Melefan (plates 3 and 4, figure 12). The angle of discordance between the steeply southward dipping Selmo and overlying gently tilted clastics decreases southward until no discordance is present and the two units are gradational.

These continental, unconsolidated clastics consist mostly of poorly sorted, thick-bedded conglomerates with a clayey calcareous matrix. Grey-brownish coarse sandstone intercalations and shale partings are also present. The variable rock components were derived from the rising northern orogenic belt.

ii. Firki clastics. This is a coarse clastic formation 200-300 meters thick and similar to the Lahti formation. It overlies the Lice group conformably to the northwest outside the project area. The formation is well developed in the Firki area north of Hamzali. The name Firki clastics is suggested from this type locality (figure 13).

The Firki clastics are thick-bedded, poorly sorted, poorly cemented, unconsolidated, coarse sandstones and conglomerates. Limestone, serpentine, spilite, graywacke, marl and metamorphic pebbles occur in a calcareous matrix. The formation is greenish in contrast to the brownish color of the Lahti clastics.

Figure 14. Thick-bedded calcareous graywackes of the Lice group on the Sason anticline, west of Sason, looking north.

Figure 15. Sason flysch, north of Kermete on Baykan-Bitlis road, looking west (unit 8 of figure 31).

The northern limits of both the Firki and Lahti clastics follow the southern thrust front. Neither formation has been overridden by thrust blocks in the studied area. Both formations are molasse type, post-tectonic deposits formed in exogeosynclinal basins in front of the orogenic belt after the diastrophic phase was complete and uplift commenced.

e. Quaternary terrace and alluvium deposits

Several large and small remnants of flat lying, unconsolidated conglomeratic terrace deposits occur in the area (plate 2). They form steep bluffs along the Sason and Garzan rivers. Sorting and cementing of the sediments is poor. Rounded pebble-to boulder- size limestone, chert, sandstone and metamorphic rock pebbles constitute the bulk of the terrace components. The terrace surface occurs at about 1000 meters elevation and is some 20-30 meters higher than the present flood plain.

A thin veneer of alluvium usually covers the valley bottoms. Both the terrace deposits and alluvium are widespread in the southern plains, gradually disappear to the north.

3. Allochthonous geosynclinal sediments

Two distinct thrust slices of geosynclinal type sediments constitute this group. The lower slice is 1000-1500 meters thick and consists of uniform green marls, graywackes and shales. These are called the Lice group in this report. The overlying slice is 1500-2000 meters thick and consists of diverse lithologic types including red marls, green flysch, black micrites and red clastics. These are termed the Sason-Baykan group. Serpentines and spilites are important components of this group. Lice sediments were deposited on the outer flanks

Figure 16. Section of Baykan group, north of Memla, on Rafcali tepe, looking northwest. 1)red sandstone, 2)black micrite, 3)spilite, 4)red marls (units 5 to 8 of figure 27).

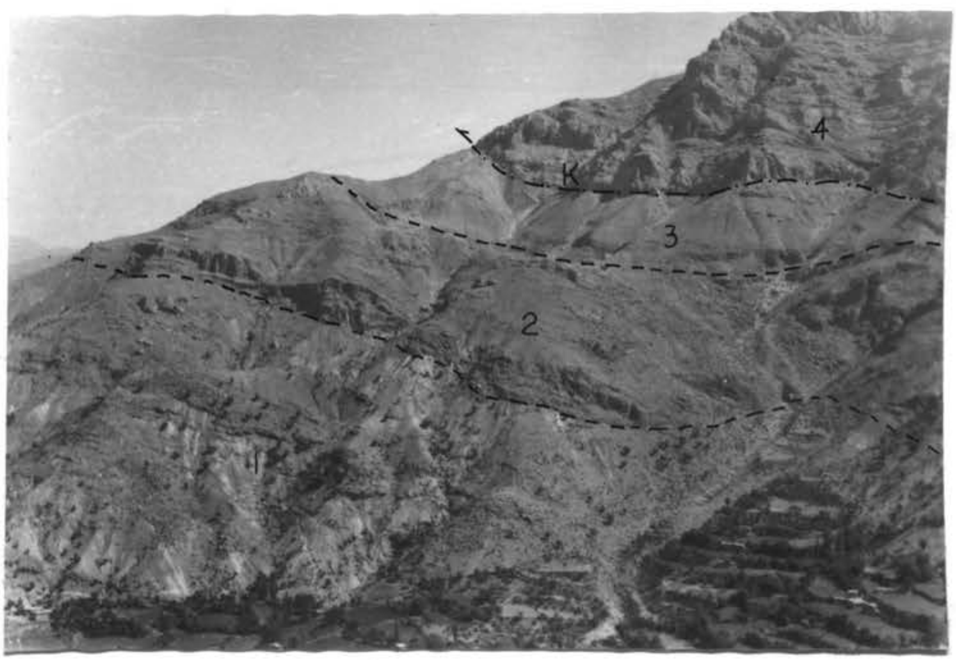

Figure 17. View of the allochthonous block, east of Sason, looking north, 1)quartzites, 2 and 4)calc-schists and crystalline limestones, 3)non-metamorphic graywackes and marls, k. Kale thrust (units 11 to 19 of figure 26).

of a geosynclinal basin in front of the Bitlis Massif. The Sason-Baykan group was deposited in the inner eugeosynclinal portions. The age of these sediments range from Eocene to Miocene.

The northern flank of the Golap anticline is covered by green-colored 1000-2000 meters thick, graywackes, shales and marls. These sediments can be followed west along the Foothill Belt as far as Ergani to the northwest of Diyarbakir. They cover an extensive area north of Hazro uplift around Lice and Kulp. These green calcareous graywackes, shales and marls are called the Lice formation from its type locality in literature (RIGHI and CORTESINI, 1964). It is considered to be a molasse-type deposit which accumulated in a narrow, post-tectonic basin of limited extent during Miocene time aroung Lice (RIGHI and CORTESINI, 1964, TOLUN, 1960, ALTINLI, 1966)(figures 5 and 6).

To the east near Melefan, Baykan and Ziyaret, green graywackes and shales are thrust southward over the Selmo formation. The overthrust sheet is in turn overthrust by another group of sediments and basic igneous rocks. The lower uniform green, graywacke-shale series, and the overlying, vari-colored, eugeosynclinal sediments are considered to be a gravity slide complex of Upper-Cretaceous-Paleocene age by all geologists who have worked in the area such as ARNI (1939), TOLUN (1960), and ALTINLI (1966).

The presence of reworked fossils and exotic gravity slide blocks may have been factors which apparently misled many workers in the area.

Regional correlation of the allochthonous geosynclinal sediments based on petrographic and paleontologic studies of various undisturbed stratigraphic sections and detailed mapping disclose that the eugeosynclinal sediments of the allochthonous block in the Sason-Baykan area

Figure 18. Blue marls (1), conglomerates (2), and green graywackes and shales (3) with conglomerate lenses (4), of the Sason-Baykan group, east of Madar, looking northwest (units 4 to 7 of figure 32).

Figure 19. Red and blue marls (1), and grey compact sandy limestones (2) of the Baykan group, east of Minar, looking east.

are Eocene to Miocene in age. This is also substantiated by radioactive age determinations of spilite samples from these series.

The Lice graywackes and shales are not a post-tectonic deposit. They accumulated on the outer flanks of a eugeosynclinal basin while marls and flysch, with accompanying basic volcanic rocks, were deposited in the inner portions, Hence the Lice as well as the Sason-Baykan group represent, characteristic lithologic associations of different tectono-environments within the Lice-Baykan geosynclinal trough.

In a similar fashion to the above, the Selmo and Germik formations constitute particular lithologic associations of the marginal basin which was coupled with the northern trough by a west-northwest hinge line. Lahti and Firki clastics are truly post-tectonic, molasse-type sediments.

The Lice and Sason-Baykan groups are not chaotic gravity slide complexes. They occur as two distinct allochthonous thrust slices. During Late Miocene orogeny the Lice outer flanks sediments were thrust southward onto the Selmo-Germik marginal basin deposits and were in turn thrust by the Sason-Baykan eugeosynclinal inner rim sediments of the northern frontal trough.

Regional correlation of the allochthonous and autochthonous sediments indicates that a dominantly non-clastic followed by a dominantly clastic stage of sedimentation occurred throughout the region after Eocene time. The non-clastic stage is represented by evaporites in the southern marginal basin, lower bluish shaly marls of the Lice group on the flank, and red and blue marls, chert, spilites and serpentines in the inner eugeosynclinal portions of the frontal trough.

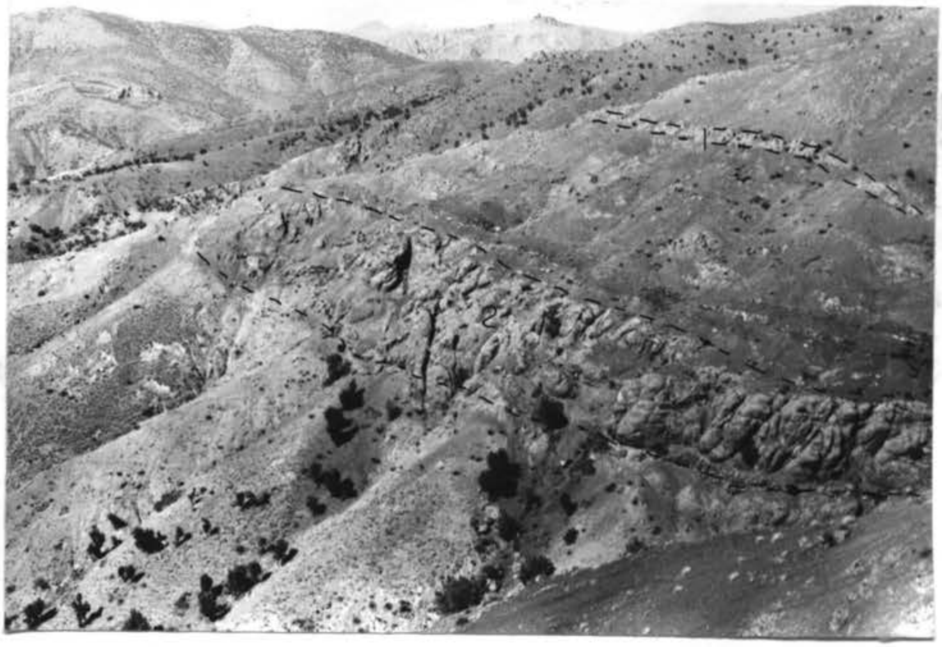

Figure 20. Spilites of the Baykan group with marl (1), and agglomerate (2) intercalations, north of Melefan, looking nortwest.

Figure 21. Black micrites and sandy intrasparites of the Baykan group, north of Homent, looking north (units 12 and 13 of figure 28).

The clastic phase is represented by red sandstones in the marginal basin, as poorly stratified, calcareous, coarse graywackes and shales of Lice group on the flank, and as dark green flysch in the eugeosynclinal portion of the trough. Another brief stage of non-clastic deposition and volcanic activity followed the flysch. This stage marks the end of the subsidence period. Sedimentation continued in the northern trough which was filled with clastic material derived from the northern rapidly rising landmass.

The equivalent of the Midyat limestones occurs as an areally persistent 5-10 meters thick buff-colored biomicrite layer within the Sason-Baykan group. The overlying sediments correspond to the Germik-Silvan-Selmo formation of the southern marginal basin. The underlying sediments correpond to the Antak formation.

a. Lice group

The Lice group overlies the Silvan limestone conformably on the northern flank of the Golap anticline (plate 3). The latter formed a part of the hinge between the eu- and miogeosynclinal basins during Oligocene - Miocene times. The thickness of the group varies between 1000-1500 meters. SALTIK and OKTAY (1969) measured 1110 meters on the northern flanks of the Golap anticline. The upper 1384 meters of the rocks drilled at the Meselik locality consists of green graywackes, shales and marls of the Lice group.

Regionally, the group can be roughly divided into a lower non-clastic or shale-marl, and an upper clastic portion. Near the hinge belt, around Golap, the lower portion consists of poorly stratified, light green, calcareous, fissile shales with chalky reef limestone

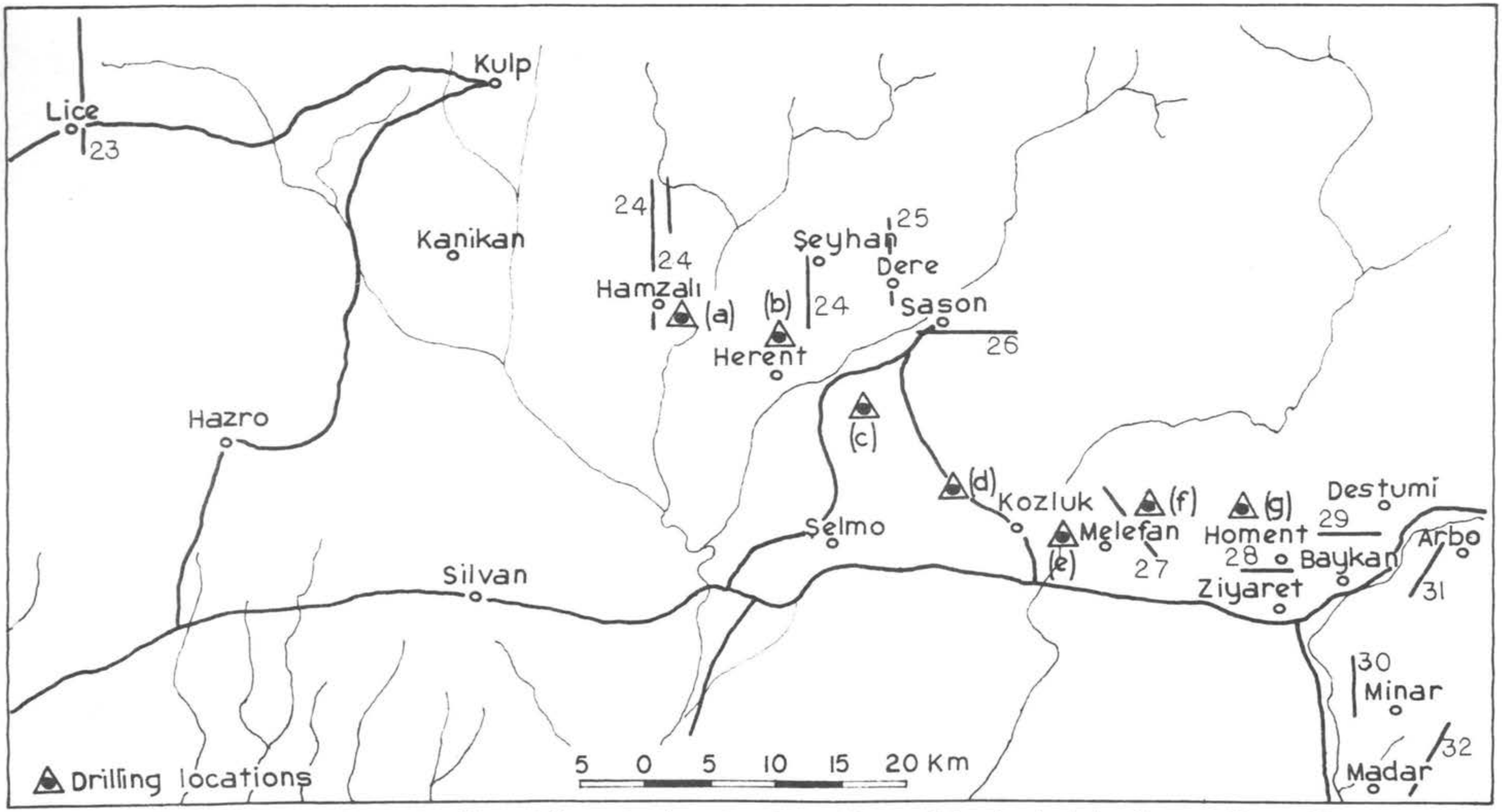

Figure 22. Index map of the stratigraphic and structural sections illustrated in figures 23 to 32. Location of the drill holes referred to in the text are also indicated. a. Golap, b. Herent, c. Gemik, d. Bolukkonak, e. Alicli, f. Yazpinar, g. Meselik drill holes. Locations are approximate.

and sandstone intercalations. Algal limestones, confined to the hinge belt, are buff-colored and consist of large or small algal fragments and varying amounts of benthonic foraminifera in sparry, micritic matrix. Subordinate detrital material may also be present. They may grade into biosparites and intrasparites. Partial recrystallization and dolomitization occurs within these reef carbonate beds.

The upper portion of the Lice group consists of coarse-grained poorly stratified or medium-to thick-bedded calcareous graywackes and conglomerates with subordinate shale interlayers in the vicinity of the hinge. A reef limestone layer of limited areas extent occurs within the upper portion. This grades into conglomerates to the west.

High carbonate content in the matrix, coarse grain size, scarcity of chlorite and magnetite and presence of fossil fragments distinguish these calcareous graywackes of the Lice group. Three north-south sections of the Lice group on the northern flanks of the Golap anticline are shown in figure 24. The fossil assemblage indicates a Miocene age.

An extensive spilite lense occurs within the upper parts of the Lice group north of Hamzali. A thick lense of red sandstone and conglomerate, similar to the red clastics of the Baykan group, occurs as an eastern extension of the spilites at a slightly lower stratigraphic level. The upper and lower boundaries of the sandstone-conglomerates are gradational into the surrounding green graywackes. These red clastics and spilites are the first suggestion of a nearly typical eugeosynclinal environment.

Gradual facies change, from dominantly shallow marine facies of the hinge area into sublittoral facies northward occur away from the

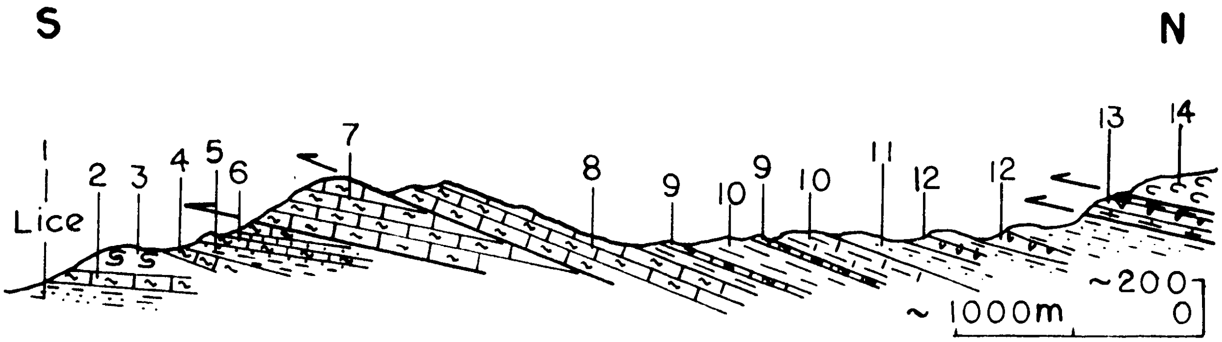

Figure 23. Stratigraphic and structural section through Lice. 1-6) Lice group. Limestones of unit 7 and 8 are possible Upper Eocene-Oligocene Midyat and Silvan equivalent. Units 9-12 are Lice group repeated by thrust faulting.

1. Calcareous graywackes and shales with Miogypsina sp., Lepidocyclina sp., Miolepidocyclina sp., Elphidium sp., Amphistegina sp., Globogerina sp., and textularids.

2. Buff-colored algal biomicrite with Bolivina sp., Orbulina universa, Lepidocyclina sp. (?), Globigerina sp., Globorotalia sp., algae and textularids.

3. Serpentine wedge.

4. Reddish-buff colored, conglomeratic, sandy micrite with serpentine pebbles.

5. Green flysch, red marl, black micrite and sandy intrasparite series with Globorotalia, Globigerina, Bolivina, miliolids, and rotalidae.

6. Fossiliferous algal biomicrite with Amphistegina, Miogypsina, Operculina, and algae.

7. Fossiliferous intrasparite to biomicrite, thick bedded, sandy at the base with subordinate algal fragments, detrital material and Tritaxia, and miliolids.

8. Thick-bedded buff-colored fossiliferous algal micrite with Lepidocyclina sp., Miogypsina sp., Amphistegina sp., Textularia sp., Globigerina sp., Miolepidocyclina sp., and algae.

9. Single 3 to 10 meters thick layer of algal biomicrite beds.

10. Flysch-like alternation of shaly and sandy blue marls with planktonic foraminifera in a clayey carbonate matrix and varying amounts of detrital material with Globigerina sp., and Globorotalia sp.

11. Green flysch, regular thin-bedded alternation of green graywackes and shales. Similar to the Sason flysch in the east.

12. Spilite lenses within the flysch of unit 11.

13. Intercalated series of marls and spilites.

14. Metamorphic rocks.

hinge belt. Calcareous shales with reef limestone intercalations bearing benthonic foraminifera, grade into bluish, medium-bedded marls with planktonic foraminifera. The coarse-grained, poorly stratified, calcareous graywackes and conglomerates grade into thin-bedded, dark green flysch.

The Lice section which conformably overlies the thrusted biomicritic limestones of Midyat silvan equivalent (unit 8 of figure 23) consists of blue marls and overlying flysch north of Lice (units 9 to 12). The marls sometime occur as flysch-like alternations of shaly and sandy variations. These are characterized by speciments of _Globigerina_ and _Globorotalia_ in an argillaceous carbonate matrix. The flysch consists of regularly alternating, thin-bedded graywackes and shales. Medium to fine angular to subangular quartz and feldspar grains and a dominantly clayey matrix constitute the graywackes. Subordinate amounts of opaque mineral, biotite and detrital material are also present.

Lenses of spilites and red marls occur more frequently in this locality within the upper portion of the Lice group. Along with the dominantly pelagic facies, these spilites indicate the eugeosycnlinal portion is nearby. Indeed, the lower marl and upper flysch sequence of the Lice group in this locality matches the marls and flysch sequence overlying the biomicrite layer of Midyat equivalent within the allochthonous eugeosynclinal Sason-Baykan sediments (figure 33).

The exact stratigraphic position of the neritic buff-colored algal biomicrites, which occur as intercalations with green calcareous shales and graywackes as well as pelagic black micrites north of Lice (units 1 to 6 of figure 23), is not known.

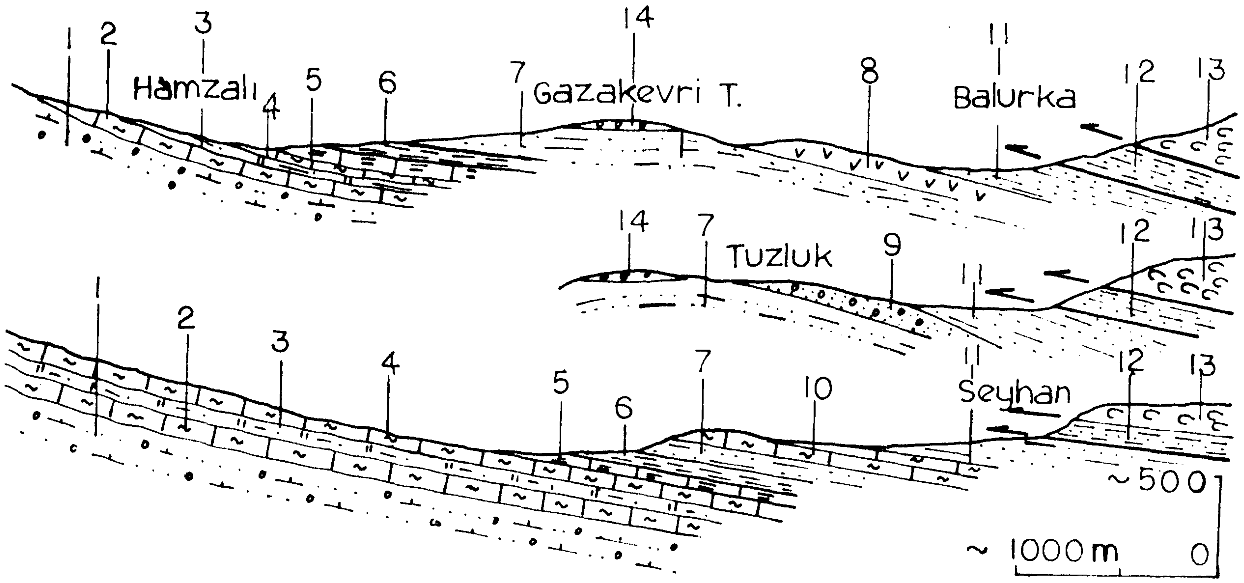

Figure 24. Stratigraphic and structural section through Hamzali, Tuzluk and Seyhan. 1)Antak formation, 2)Midyat limestones, 3)Germik formation, 4)Silvan limestone, 5-11)Lice group, 12)Sason flysch, 13) Metamorphic rocks, 14)Firki clastics.

1. Red clastics with red marl interlayers.

2. Buff-colored biomicrite with Praerhapydionina (?), Tritaxia, Archaias (?), miliolids, and ophthalmidids.

3. Red evaporites and shales with ostracods.

4. Algal limestone , algae and other fossils in micrite and spar with Globigerina sp., Globorotalia sp., Eponides, Neoalveolina, Dentalina, and ophthalmidids.

5. Fissile, chalky limestone and bluish fissile marls with abundant fossils and algal fragments and some quartz in micrite and spar. Amphistegina sp., Elphidium sp.,miliolids, ophthalmidids, and bryozoa present.

6. Green carbonaceous shales.

7. Green calcareous graywackes and shales.

8. Spilites and agglomerates. A limestone boulder in the agglomerates contain Discocyclina sp., Planorbulina sp., Globigerina sp., miliolids, brozoans, and ophthalmidids.

9. Red sandstone and conglomerate layer within green graywackes with gradational contact. Slightly lower stratigraphic level than the spilites.

10. Buff-colored algal biomicrite and conglomerate with Amphistegina sp., Textularia, Operculina, Elphidium, Neoalveolina sp., Rotalia, Archaias, Dentalia, miliolids, bryozoans ophthalmidids.

11. Green calcareous graywackes.

12. Dark green flysch. Graywackes are finer-grained than unit 11 and have chlorite in matrix.

13. Metamorphic rocks.

14. Coarse, calcareous sandstones and conglomerates.

The fossil content is similar to that of the biomicrites (unit 8) which underlies the Lice group. The fossils suggest an Uppermost Oligocene to Lower Miocene age. It is assumed that these sediments, which also include a serpentine wedge either constitute the lowermost portion of the Lice group or are equivalent to the Silvan formation. They were brought to the surface by thrusts or reverse faults.

The uniformly green Lice group crops out in a fenster under the Sason-Baykan eugeosynclinal sediments around Ziyaret to the west of the mapped area. Another large fenster exposes the group northeast of Baykan and east of the Bitlis road. At the Meselik locality (figure 22) 1384 meters of dominantly shaly Lice section was drilled. This section is within a partial fenster (bounded by thrusts on three sides), north of Ziyaret and above the underlying autochthonous red clastics and salts of the Selmo formation. The upper sequence consists of 804 meters of green sandy shales and sandstones with rare, red-colored variations, 140 meters of conglomerates and sandstones, 210 meters of sandy shales with 20 to 30 meters of thick red shale intercalation in the middle part, 220 meters of green shaly marls with an uppermost 60 meters of green and red shales and sandstones. This succession does not match well with the observed autochthonous Lice section to the west. A thrust fault is suspected at a depth of 300 to 400 meters which may cause repetition of the sequence.

These uniform green graywackes and shales are though by many including ARNI (1939), and TOLUN (1960) to belong to the Upper-Cretaceous-Paleocene geosynclinal gravity slide complex. They report characteristic Upper Cretaceous index fossils, such as Globotruncana, from the green graywacke shale series. Indeed, in the upper 430 meters of sediments drilled at Meselik, reworked *Globotruncana stuarti*, *Globotruncana* sp., occur along with *Globigerina*, *Globigerinoides*, and *Globorotalia*. The lower part contains abundant reworked Eocene fossils such as *Discocyclina*, *Nummulites*, *Amphistegina*, *Rotalia*, *Cibicides*, *Globigerina*, and gastropods. A sample from the Lice sediments northeast of Baykan on the Bitlis road contains *Lepidocyclina* sp., *Globigerina* sp., *Operculina* sp., and *Eponides* sp. suggesting an Oligocene to Miocene age.

Some andesite inclusions were observed within the Lice sediments west of Kulp.

b. Sason-Baykan group

A series of red marls, clastics, flysch and limestones with accompanying spilites and serpentines comprise the allochthonous Sason-Baykan group. These make up the northern eugeosynclinal equivalent of the autochthonous Antak, Midyat, Germik, Silvan and Selmo-Lice sections.

The sequence consists of lower and upper red marl-clastic sections and a green flysch series between. The flysch is called the Sason flysch specifically and the red marl-clastic series, the Baykan group. The uppermost portion of the upper red marl-clastics of the group consist of thick red conglomerates. These conglomerates are referred to as Karatepe subgroup.

Within the Sason and Kozluk area, which includes the major portion of the mapped area, the Baykan group is thin and intensely disturbed. This is probably due to the drag effect of the overlying allochthonous metamorphic block. Representative, undistrubed sections occur only north

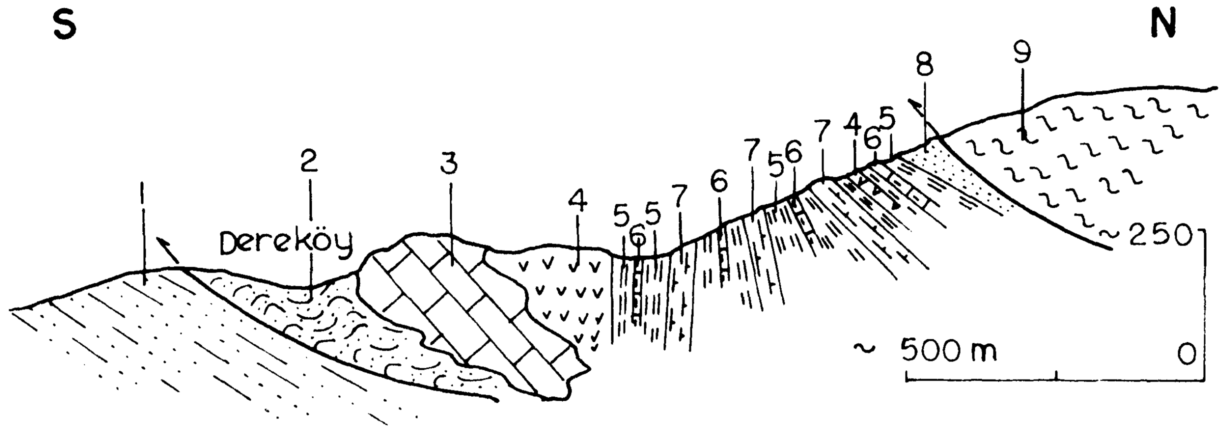

Figure 25. Stratigraphic and structural section through Dere. 1)Lice graywackes, 2)Sason flysch, 3)An exotic block of crystalline limestone, 4-8)Baykan group, 9)Calc-schists.

1. Light green graywackes, medium-fine angular grains of quartz, and feldspar in argillaceous carbonate matrix, with some impurities.

2. Dark green graywacke and shale alternation. Graywackes are finer-grained with chloritic clayey matrix and a greater percent of opaque minerals than underlying Lice graywackes. Fossils; Discocyclina, Rotalia.

3. An olistolite of crystalline limestone.

4. spilite.

5. Red and grey mudstones, silt-size quartz and feldspar in clayey or ferruginous matrix with or without scarce planktonic foraminifera. Fossils; Globigerina sp.

6. Thin-bedded flysch-like interlayers of black micrite and sandy intrasparite. Sometimes single layers of sandy silty compact grey limestone within mudstones. Micrites, mudstones, silty limestones and intrasparites are all gradational. Fossils; Globigerina sp., Globorotalia crassata.

7. Thick (3-10 meters) single interlayers of red marl within mudstones. Marls consist of planktonic foraminifera in ferruginous carbonate matrix.

8. Red sandstone, moderately angular quartz and feldspar grains, alteration products and scarce opaque minerals in ferruginous carbonate matrix.

9. Calc-schists.

of Melefan, Dere and Beksi (plates 2 and 4).

The Sason-Baykan group is 1500-2000 meters thick and is relatively undisturbed around Baykan. Although Baykan area is outside of the mapped one, a few stratigraphic sections were studied in order to obtain a regionally correlated stratigraphic sequence of the group.

i. Rock types. Clastic rocks, limestones, marls, and flysch are the main lithologic types. Spilites and serpentines make up the igneous components. Clastics vary in grain size from fine mudstones to coarse massive conglomerates. The clastics are predominantly red, but grey mudstones and conglomerates are also present, often in close association with red varieties. Buff-colored neritic biomicrite, black pelagic micrite, sandy grey intrasparites are the main limestone types. The buff colored neritic biomicrite occurs as a single areally persistent layer and is locally underlain by a buff calcareous conglomerate. The carbonate unit is equivalent to the Midyat limestone.

Marls occur as blue or red, medium-bedded rocks with typical conchoidal fracture. Planktonic foraminifera such as Globigerina and Globorotalia characterize both the marls and black micrites. The flysch consists of regularly alternating, thin-bedded graywackes and shales. Laminated black micrites and sandy-grey intraclastic limestone may also occur as flysch-like regularly alternating series. A few grey chert layers occur at different stratigraphic levels. Some of the marls contain Radiolaria along with Globigerina and Globorotalia. These marls are distinguished by their greater resistance to weathering and calcite-filled fractures.

The bulk of red clastics occurs in the upper clastic marl layer of the Sason-Baykan group. Mainly red conglomerates constitute the

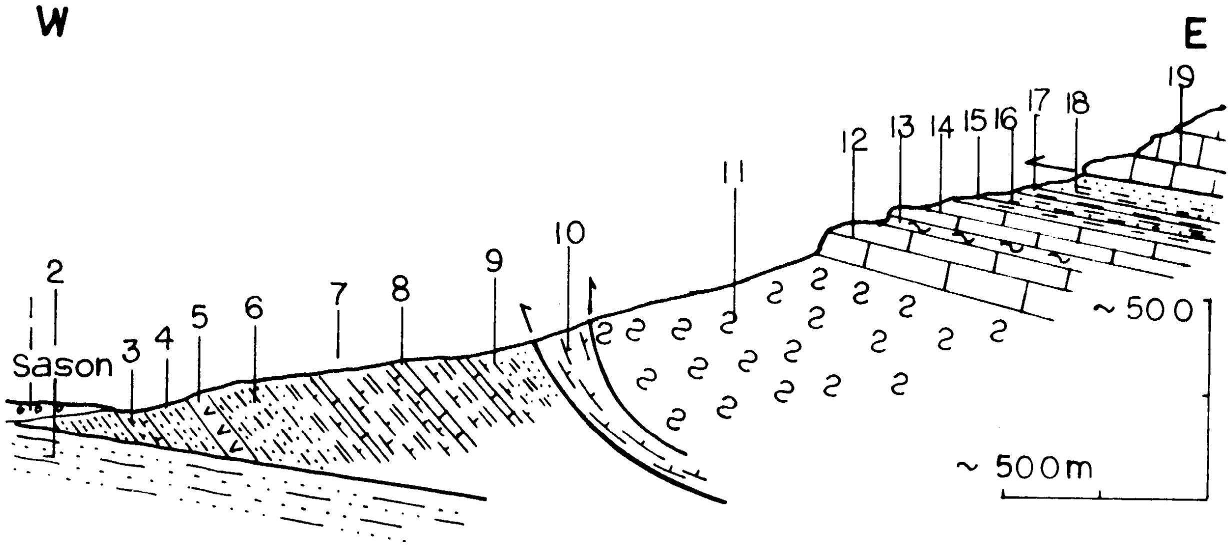

Figure 26. Stratigraphic and structural section east of Sason, 1)Quaternary terrace deposits, 2)Lice graywackes, 3-9)Sason-Baykan group, 10)backdeep sediments, 10-19)allochthonous metamorphic block with an interthrust layer of non-metamorphic backdeep sediments (15-18).

1. Coarse calcareous conglomerates.
2. Green calcareous graywackes and shales.
3. Single layer of red marl within green flysch.
4. Dark green graywacke and shale alternation. These constitute the Sason flysch which is gradational upward into the Baykan series in this locality. Graywackes of the flysch consist of silt to sand-sized angular grains of quartz and feldspar in a clayey, chloritic, calcareous matrix with some impurities and opaque minerals.
5. Lense of spilite within flysch. Absolute age is 33.2 million years (Oligocene).
6. Flysch grading into flysch-like alternation of black micrite and grey sandy limestone.
7. A series of red marls, mudstones, black micrites, sandy intrasparites, green flysch, with Globigerina sp., and Globorotalia sp.
8. Layers of platy black micrite with Globigerina and Globorotalia.
9. Sequence of red marls, red and grey mudstones, green flysch and red sandstones.
10. Sequence of red marls, sandstones, and red and grey mudstones.
11. Green-schists and quartzites.
12. Massive crystalline limestones.
13. Calc-schists.
14. Massive crystalline limestones.
15. Red and grey silicified rocks and red marls.
16. Green medium-grained graywackes.
17. Red marls with Globigerina sp., and Globorotalia sp.
18. Green medium-grained graywackes.
19. Massive crystalline limestones with local interlayers of calc-schists at the base.

Karatepe subgroup north of Melefan. Red and grey mudstones and siltstones constitute this upper layer in the Sason area.

Pebbles of metamorphic rocks, crystalline limestone, and less abundant marls and graywackes, and a silty ferruginous matrix make up the poorly stratified, massive red conglomerates of the Karatepe subgroup. Huge exotic blocks of crystalline limestone, a grey limestone breccia of subangular limestone fragments cemented by carbonate, red sandstones and red and grey mudstones are the main associates.

A brownish grey conglomerate occurs as a layer or lenses within the lower marl-clastic part of the Sason-Baykan group (figures 18 and 32). Pebbles of Eocene biomicrite, serpentine, spilite, marl and graywackes are the components.

A third type of conglomerate occurs locally under the buff biomicrite key horizon. Subangular pebbles of the same limestone and carbonate matrix comprise these rocks.

A green calcareous conglomerate and coarse sandstone layer occur within the upper marl-clastic series of the Baykan group, north of Melefan. This layer is identical in lithology to the coarse calcareous sandstones and conglomerates of the Lice group in the vicinity of the hinge.

Red sandstone beds occur as intercalations with other rock types within the lower marl-clastic layer (figure 16). Coarse to fine, poorly sorted, angular to subangular grains of quartz and feldspar, some rock fragments in a ferruginous matrix constitute these rocks. The red sandstones of the upper marl-clastic layer of the Baykan group are poorly stratified and occur in close association with conglomerates. These

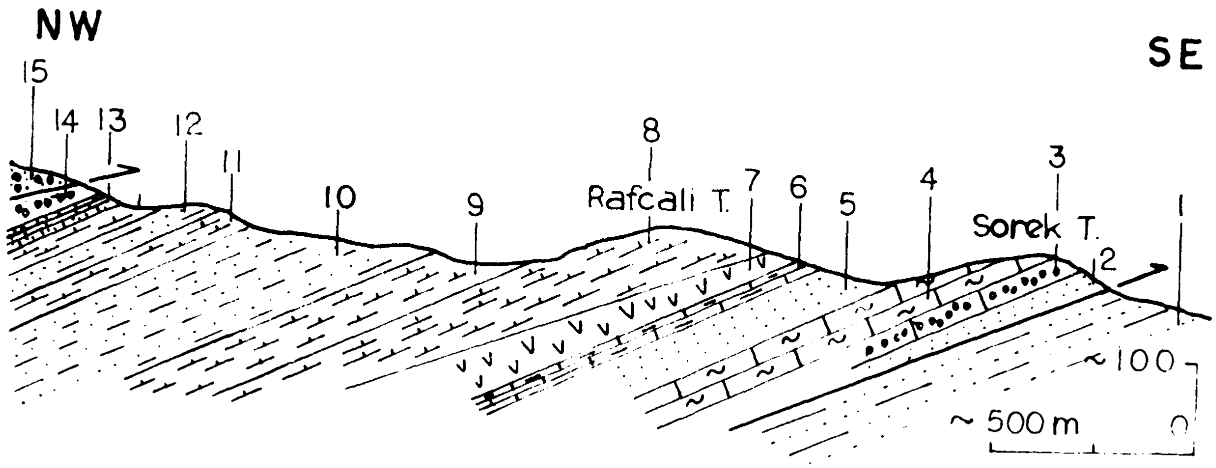

Figure 27. Stratigraphic and structural section north of Memla, 1)Lice graywackes, 2-14)Baykan group with Sason flysch tongue (10), 15)Karatepe red conglomerate subgroup.

1. Green calcareous graywackes and shales. Fine, moderately angular quartz and subordinate feldspar, few opaque minerals and rock fragments and alteration products in an argillaceous carbonate matrix constitute the graywackes.

2. Red sandstone, fine angular quartz and feldspar grains, hematite and subordinate rock fragments in ferruginous matix.

3. Calcareous limestone conglomerate.

4. Buff-colored micrite, medium-thick-bedded. No fossils known but this unit is a key horizon. It is equivalent to the Eocene Midyat limestone with identical field characteristics.

5. Red sandstone, fine to medium grained angular quartz and feldspar, and hematite in a ferruginous matrix.

6. Thin-bedded black micrite with planktonic foraminifera.

7. Spilites with phenocrysts of plagioclase (labrodorite) in a mafic groundmass with abundant microlites. Absolute age is 35.6 million years (Oligocene).

8. Red marls, planktonic foraminifera in ferruginous matrix.

9. Blue marls, planktonic foraminifera and silt in a clayey carbonate matrix.

10. Dark green graywacke and shale alternation.

11. Red marl.

12. Light green calcareous graywackes and conglomerates identical to Lice graywackes.

13. Red marl.

14. Black micrite with planktonic foraminifera, also sandy or pure intraclastic limestone with sparry matrix, often in flysch-like alternating relation wiht black micrites. Fossils; *Globigerina* sp., *Globorotalia* sp., *Globorotalia aragonensis*, *Tritaxia*, *Lepidocyclina*, *Nonion*, and *Rotalia*.

15. Red conglomerates and sandstones.

have a higher percent of rock fragments and iron oxide cement. The matrix is silty rather than clayey and comprises less than 25 % of the volume.

Red and grey siltstones and mudstones occur as laminated, 5-10 cm thick intercalations with black micrites and sandy intraclastic limestones. Both in the lower and upper marl-clastic sequence of the Baykan group. Absence or scarcity of planktonic foraminifera, lower carbonate content in the matrix, red color and presence of silt distinguish these rocks from the black micrites. The green mudstones are distinguished from shales by their lighter color and carbonate content.

The Midyat equivalent biomicrite occurs as a single 5-20 meters thick, buff-colored, jointed, distinctive limestone layer with lithographic to finely crystalline appearance, and is resistant to weathering. It consists of benthonic foraminifera, subordinate intraclasts, algal and rock fragments, rare quartz and feldspar grains in a micritic groun-mass. Local variations into pure micrites and biosparites are present, although the layer has a rather uniform appearance in the field.

The boundaries of the unit are distinct, but towards the north it grades into black pelagic micrites with planktonic foraminifera. These black micrite and grey intrasparites, which often occur as flysch-like alternations, constitute an important facies of the Baykan group The black micrites are thin-bedded, laminated to platy, and weather typically white to buff. The presence of planktonic foraminifera such as Globigerina and Globorotalia is characteristic. Benthonic foraminifera are usually absent. Certain amounts of argillaceous material, opaque minerals and silt may also be present. Gradation into mudstones or into sandy intrasparites are common.

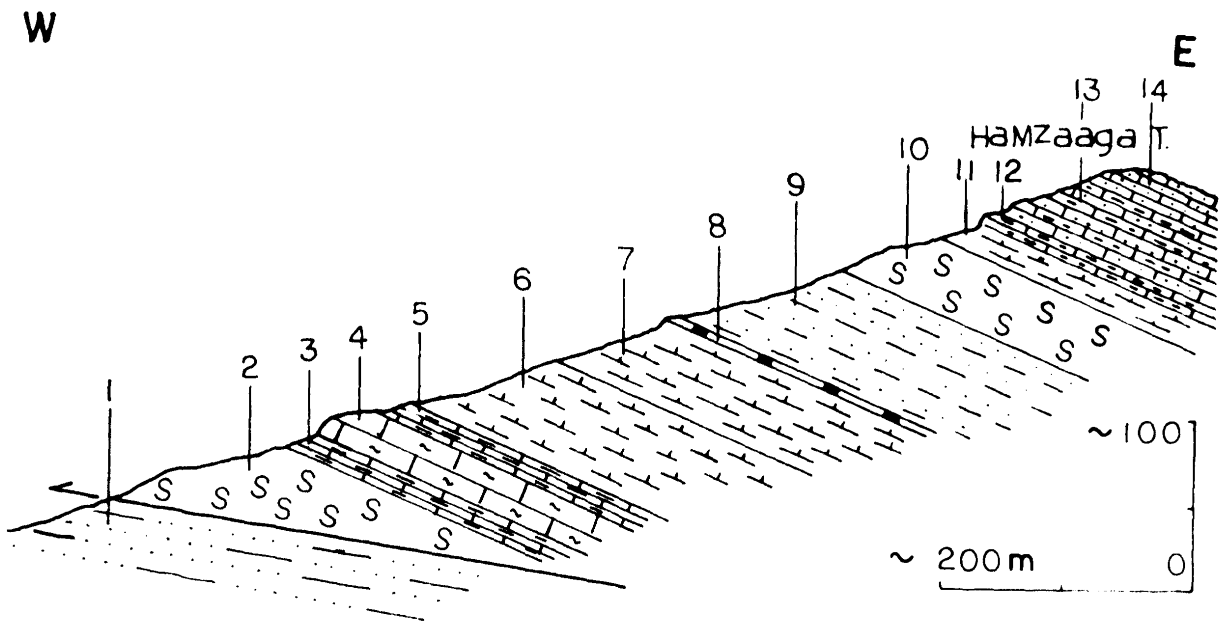

Figure 28. Stratigraphic and structural section through Homent. 1)Lice graywackes and shales, 2-14)Baykan series with Sason flysch tongue (8).

1. Light green, poorly stratified calcareous graywackes and shales.
2. Serpentine.
3. Thin-bedded, platy black micrite with Globigerina sp., and Globorotalia sp.
4. Buff-colored biomicrite, key horizon-equivalent of Midyat limestone, mostly benthonic foraminifera in micrite with subordinate spar, includes Orbitolites sp., Nummulites sp., Alveolina pasticillata, Discocyclina sp., Alveolina sp., Valvulinida, and miliolids.
5. Thin-bedded black micrite with Globigerina and Globorotalia.
6. Red marls with Globigerina and Globorotalia.
7. Blue marls with silt-sized quartz and planktonic foraminifera in clayey carbonate matrix.
8. Silicified layer.
9. Thin-bedded regular alternation of dark green graywackes and shales.
10. Serpentine.
11. Red marl with radiolaria in ferruginous carbonate matrix.
12. Laminated black micrite with planktonic foraminifera.
13. Regular alternation of laminated black micrite and grey sandy intrasparite which have a flysch-like appearance.
14. Grey compact sandy intrasparite. Fine to medium quartz and feldspar grains in a finely crystalline impure carbonate.

The grey intrasparites occur as compact sandy or pure medium-to thin-bedded limestone with a crystalline appearance. The origin of this rock is problematic, because in some cases the sparry matrix constitutes more than 80 % of the rock. Its close association with black micrites and the presence of intraclasts eliminate recrystallization as a possible explanation. Yet, it is difficult to conceive how almost pure spar limestone can locally exist as a result of sedimentation on the sea bottom.

Red and blue marls are the principle constituents of the lower marl-clastic layer of the Baykan group. They are gradational and recognized by their reddish or bluish grey color, medium-to thin-bedding, brittleness, conchoidal fracture and lithographic appearance. Their principle constituents are micrite and clay. They may locally grade into mudstones.

Planktonic foraminifera such as Globigerina and Globorotalia form a diagnostic component of marls. Radiolaria also occur rarely. Fossils may compose from 5 to 90 % of the rock, although it is usually around 20 %. A subordinate amount of rock fragments, opaque minerals, and quartz grains are generally present. The red marls contain iron and manganese oxide in the matrix. The radiolaria-bearing marls seem to be more competent and resistant to weathering. Calcite-filled fractures are common to this rock type.

Flysch, which constitutes a major portion of the allochthonous sediments, consists of regularly alternating 5-10 cm thick layers of green graywackes and shales. Gradations from calcareous graywackes into non-clastic sediments, or siltstones and shales are common.

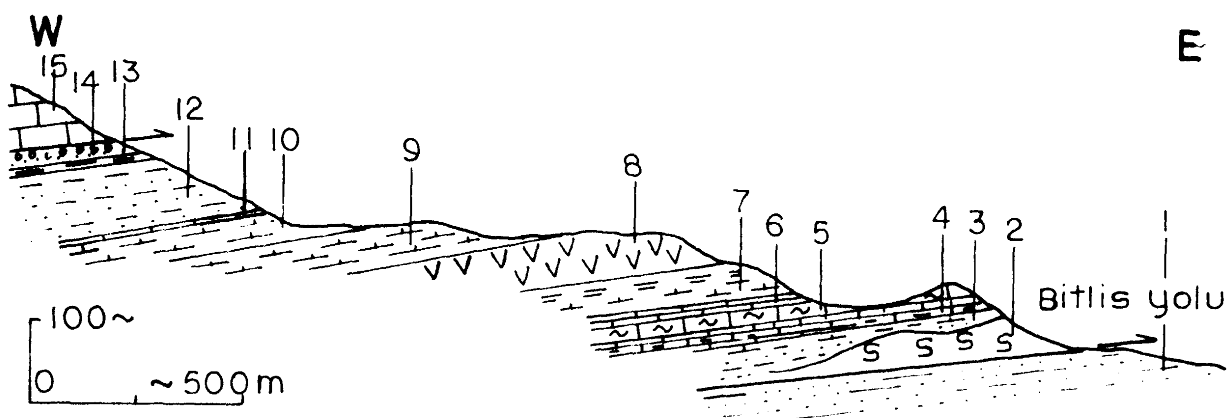

Figure 29. Stratigraphic and structural section south of Destumi. 1)Lice graywackes and shales, 2-14)Baykan red marl-clastic series with Sason flysch tongue (12), 15)crystalline limestone.

1. Light green calcareous graywackes, medium-fine angular quartz and feldspar grains, opaque minerals, rock fragments and Lepidocyclina sp., Globigerina sp., Operculina sp., Eponides sp., in carbonate matrix.

2. Serpentine.

3. Dark green graywacke and shale alternation and marls.

4. Thin-bedded black micrite of small planktonic foraminifera and fine impurities in micrite, or gray sandy intraclastic limestone of quartz and feldspar grains in sparry matrix with Globigerina and Textularia.

5. Thick, buff-colored, biomicrite of benthonic foraminifera in spar and micrite matrix, partially recrystallized with ophthalmidids and miliolids, and algae. Marker horizon, equivalent of Midyat limestones.

6. Thin-bedded black micrite.

7. Red marl and mudstone of planktonic foraminifera in ferruginous matrix with and without fine-grained quartz and feldspar.

8. Serpentine, spilite with an interlayer of dark green flysch.

9. Red marl with Globigerina sp., in ferruginous matirix.

10. Blue marls with planktonic foraminifera and silt in clayey carbonate groundmass.

11. Thin-bedded black micrite with Globigerina sp., and Globorotalia sp.

12. Dark green flysch with regular thin-bedded graywacke and shale alternation.

13. Red marl.

14. Red conglomerate.

15. White,coarsely crystalline limestone.

The graywackes include medium-to fine grained angular to subangular grains of quartz and feldspar and a clayey carbonaceous matrix. Subordinate amounts of biotite, rock fragments, opaque minerals and scarce feromagnesian minerals are also present as well as glauconite, zircon, and rarely, recrystallized tiny fossils fragments. The matrix is usually greater than 25 % and mostly around 40 % of the total volume.

The flysch sequence is marly north of Baykan around Arbo village (figure 15). Slump and flow structures, graded bedding, and inclusions of large exotic blocks are common. The shales of the flysch sequence are characterized by thin lamination, dark green color and gradation into mudstones and siltstones. Sericitization is present but is not extensive.

A 2-3 meters thick buff-colored chert layer occurs within the Baykan group, north of Ziyaret (figure 26). A similar chert layer is exposed east of the Arbo village but at a different stratigraphic level. The rock consists of fine-grained quartz. Diagnostic criteria for original deposition or secondary silicification are absent. However, south of Destumi a thin black micrite layer occurs at the same stratigraphic level (unit II of figure 29). This suggests the chert layers may be of replacement type.

Spilites, and more rarely serpentines, occur as extensive lenses (figure 29) or layers of varying thickness. Spilites are dark-green to brownish-bluish and have spotted appearance. the texture of the spilites is porphyritic with large phenocrysts and microlites of labrodorite and less abundant pyroxene in a glassy groundmass. Labrodorite is commonly albitized while pyroxenes are altered to

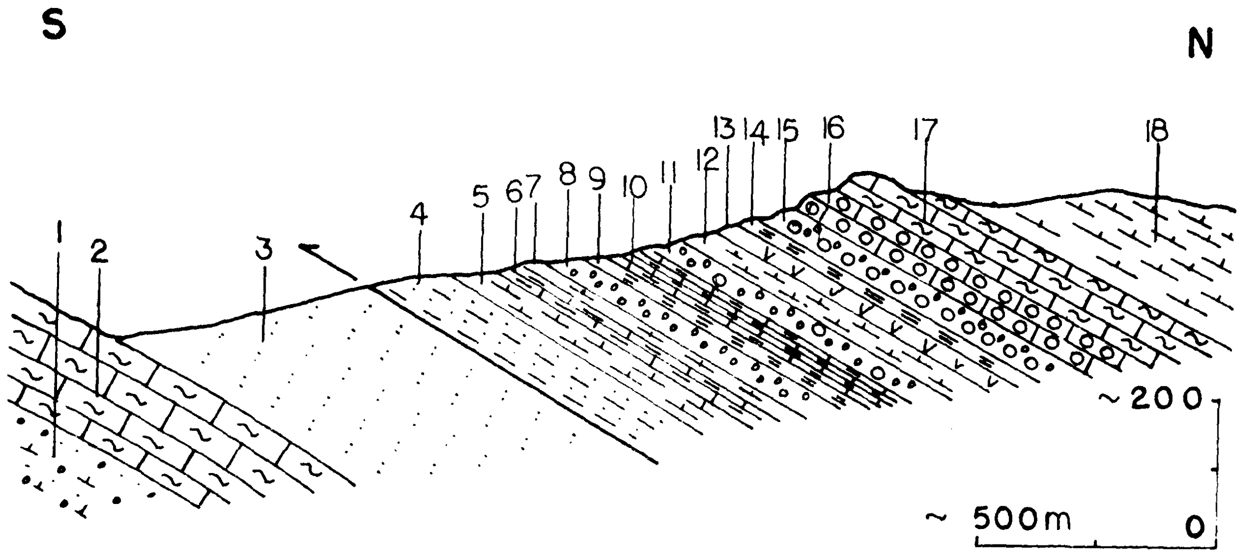

Figure 30. Stratigraphic and structural section north of Dodan anticline, west of Minar, 1)Antak formation, 2)Midyat limestone, 3)Germik and Selmo sandstones, 4-18)Baykan group. Top of section is unknown due to thrusting.

1. Red conglomerates and sandstones.
2. Buff-colored fossiliferous micrite.
3. Medium-to thick-bedded regular alternation of red and green sandstone of angular to subangular silt-to sand-size quartz, feldspar grains in ferruginous carbonate matrix, poorly consolidated.
4. Green graywackes and shales.
5. Red marls, medium thin-bedded with planktonic foraminifera in ferruginous carbonate matrix.
6. Thin bedded or platy micrite with planktonic foraminifera.
7. Red marls.
8. Red conglomerate.
9. Red mudstones with silt in clayey, ferruginous carbonate matrix and scarce planktonic foraminifera.
10. Black micrite and grey sandy intrasparite.
11. Red conglomerate.
12. Red marl.
13. Spilite.
14. Red sandstone with quartz and feldspar grains in iron oxide carbonate matrix with some rock fragments.
15. Red conglomerate.
16. Brownish calcareous limestone conglomerate.
17. Thick beds of buff-colored biomicrite consisting mostly of benthonic fossils, intraclasts and algal fragments in micrite with subordinate spar includes Alveolina sp., Alveolina pasticillata, Orbitolites sp., Nummulites sp., verneuilimidae, and miliolidae.
18. Red and upper blue marls with planktonic foraminifera in ferruginous clayey matrix.

chlorite. Pillow structures are present and agglomerates are a common associates of spilites.

Serpentine is rare within the mapped area, but do occur in masses upto 200-300 meters thick and range down to small lenses along bedding planes. These are exposed within the Sason-Baykan group in the Kulp area to the west, and in Cirri area between Melefan and Baykan. Some small lenses of serpentines are undoubtedly gravity slide blocks. However, the extensive masses most probably formed directly on the sea bottom. Occurrence of spilites and serpentines at the same stratigraphic levels also supports this view.

ii. Correlation and age relationships. Rapid facies changes, vertical repetition of lithologies, absence of fossils and inclusions of exotic gravity slide material with similar lithology make correlation of the Sason-Baykan group rather difficult. However, study of several undisturbed sections both within and outside the mapped area discloses a consistent pattern. Based on this, the upper Sason flysch tongue, the red and blue marl succession and especially the areally persistent biomicrite layer of the lower marl-clastic sequence of the Baykan group have been used as the bases of regional correlation. The age of the series is identified by the biomicrite key horizon of Middle and Upper Eocene age. Radioactive age determinations of two spilite samples from north of Melefan and east of Sason confirm an Oligocene to Miocene age of these eugeosynclinal sediments.

The undisturbed section observed north of Memla is complete and representative of the group as a whole. It also correlates fairly well with the autochthonous Tertiary section (figure 27 and 33).

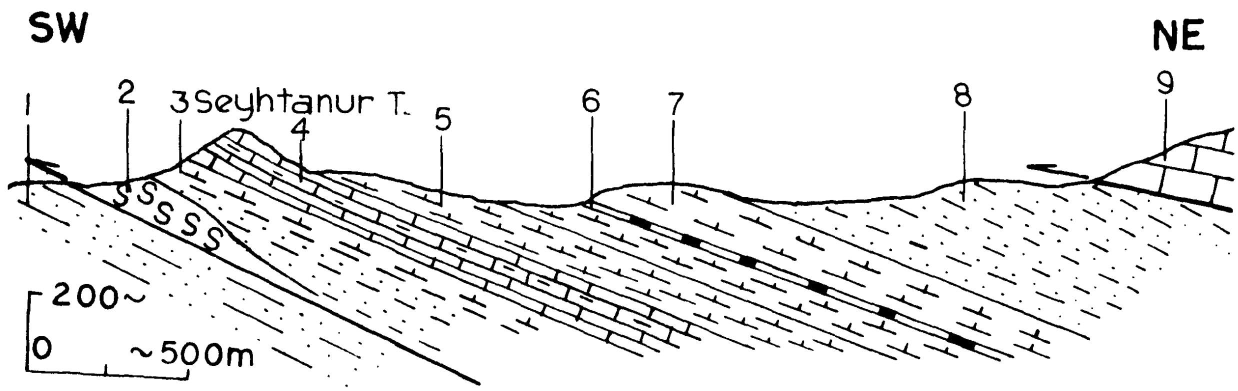

Figure 31. Stratigraphic and structural section southwest of Arbo. 1)Graywackes and shales of the Lice group. 2-8)Baykan group with Sason flysch tongue (8), 9)crystalline limestones.

1. Light green calcareous graywackes with medium angular grains of quartz, feldspar, opaque minerals and some rock fragments in a calcareous matrix.

2. Serpentine.

3. Dark green flysch and marl.

4. Thick-bedded sandy or pure intrasparite with platy black micrite partings. Finely crystalline or sparry matrix constitutes more than 50 % of the rock. Black platy micrite and sandy intrasparite occur as flysch-like alternation in some parts.

5. Red marl with planktonic foraminifera in ferruginous carbonate matrix with Globigerina sp., and Globorotalia sp.

6. Buff to grey silicified layer.

7. Blue shaly marl with planktonic foraminifera in clayey carbonate matrix.

8. Dark green flysch with regular thin-bedded, alternating graywacke and shale.

9. Massive crystalline limestones.

Figures 25 to 32 illustrate a section of the Sason-Baykan group at several localities. Brief descriptions of the rocks types and identified fossils are included under each figure.

The Sason-Baykan group is bounded by thrusts. Graywackes and shales of the Lice group underlie, and metamorphic rocks overlie it tectonically. The lower thrust approximately parallels the bedding and cuts the section at a level 10-300 meters below the Eocene marker limestone bed in the Melefan and Baykan region. Around Sason the section is faulted at a higher stratigraphic level and the lower red marl-clastic layer and the marker limestone are missing. Correlation within the upper marl-clastic sequence is poor due to rapid thickness and facies changes and lack of regionally identifiable stratigraphic horizons.

Figure 27 illustrates the section north of Memla where the general characteristics of the group are well displayed. Red clastics with a buff neritic limestone layer, red marl, blue marl and flysch and upper clastics and marls represent the basic succession of the group, although variations exist in detail. While the neritic limestone layer (unit 4 of figure 27) is not fossiliferous at this locality it is lithologically identical to the key Eocene horizon and occurs at the same stratigraphic position. Radioactive age determination of spilites (unit 7 of figure 27) indicates 35.6 $\pm$ 1.8 million years corresponding to an Oligocene age. Lepidocyclina is present in marls and limestones and the upper red marl and clastic sequence indicating an Oligocene to Miocene age.

The red sandstones and conglomerates, which underlie the key horizon include layers of red marls and black micrite north of Dodan

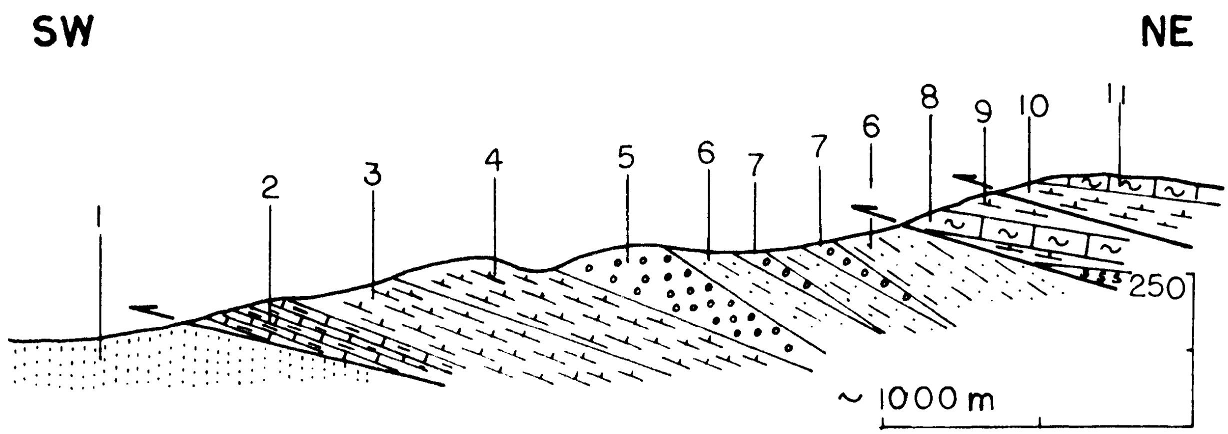

Figure 32. Stratigraphic and structural section east of Madar. 1)Selmo and Germik red sandstones, 2-7)Baykan group with Sason flysch tongue (6), 8-11)repetition of the Baykan section due to thrusting. Units 8 and 11 are believed to correspond to unit 2, and unit 9 to unit 3.

1. Red-colored sandstones overturned southward.
2. Buff-colored, medium-bedded micrite, no fossils, possibly corresponds to the Midyat limestone.
3. Medium-bedded red marl with planktonic foraminifera in ferruginous matrix.
4. Blue marls with planktonic foraminifera and impurities in a clayey carbonate matrix.
5. Browhish conglomerate with pebbles of buff-colored nummulitic biomicrite, red marl, serpentine, spilite and graywacke. Red and grey sandstone layers identical to the red and grey sandstones of the Germik and Selmo formations occur within this conglomerate.
6. Green calcareous shale alternating with graywackes. Scattered lenses of conglomerate occur within this flysch sequence which contain pebbles of nummulitic limestone (unit 7).
7. Conglomerates.
8. Buff-colored nummulitic biomicrite. Midyat equivalent.
9. Red marls.
10. Series of red marls and flysch with serpentine.
11. Buff-biomicrite, equivalent of Midyat limestone.

anticline (figure 30 and 40). These are replaced by marls, micrites, and flysch around Destumi and Arbo (figures 29 and 31). The Eocene marker bed grades from neritic into pelagic limestone to the north. A grey intrasparite and black micrite sequence occurs at the same stratigraphic level as the buff Eocene biomicrite,south of Arbo (figure 31, unit 4).

The red and blue marl and flysch sequence overlying the marker horizon is persistent and may be followed from Melefan to the Baykan area (figures 27 to 32). The Sason flysch sequence is more calcareous in the south around Madar and includes lenses of conglomerates (figures 15 and 32). The conglomerates within the Sason flysch (figure 32) contain nummulitic limestone pebbles of Eocene age, along with pebbles of serpentines, spilites, red marls, and graywackes. These pebbles were derived from erosion of backdeep sediments to the north. The latter must have been uplifted sometime after the Eocene.

The Sason flysch tongue seems to be missing north of Dodan anticline and Minar (figure 40) where only a thick sequence of blue marls overlie the key horizon (figures 19 and 30). Although the top of the section here is not known, a thick section of grey limestones overlies marls east of Minar (figure 19).

The mainly red clastic upper Baykan series becomes dominantly silty to the west and calcareous to the east. The same marl layer which overlies the flysch sequence north of Melefan is also present to the east (figures 28 and 29). A layer of light green, coarse grained, calcareous graywackes and conglomerates occurs within these marls at the Memla locality. It is identical to the graywackes and conglomerates of the Lice group in the vicinity of the hinge zone. This layer is not observed elsewhere in Sason-Baykan region. The grey sandy limestone, and black micrite sequence which overlie the marls become thicker eastward while the uppermost red clastics of the Karatepe subgroup become thinner and disappear. Although the top of the section is not known south of Homent (figure 28), further east of Minar, the thick grey sandy limestones and micrites constitute the uppermost layer of the allochthonous geosynclinal sediments (figure 19).

Westward the Sason flysch tongue increases in thickness from 100 to 500 meters near Bolukkonak, Maneran and Gemik. The exposed thickness is not more than 50 meters north of Derekoy (figure 25). The lower marl-clastic series of the Baykan group and part of the Sason flysch tongue are believed to be missing here due to thrust faulting.

Although the key horizon is not present at Sason locality, a specimen of spilites from a layer within the flysch east of Sason (unit 5 of figure 26), indicates an age of 32.2 ± 2.6 million years (see appendix 2). This places the flysch sequence equivalent to the upper Sason flysch tongue to the east. The upper red clastic series consists of intercalated red and grey siltstones, mudstones, black micrite, sandy intrasparite, and marls. Red sandstones occur as the topmost layer north of Dere (figure 25). The thick massive conglomerates and thick black micrite - grey sandy limestone series are missing in this region.

Serpentines make up an extensive mass between the Baykan and Melefan localities outside of the mapped area. One layer occurs in fault contact on the thrust plane between the Sason-Baykan group and the underlying Lice rocks. This represents the earliest stage of serpentine formation exposed in the area. The second major stage of submarine volcanic activity occur under the red and blue marl sequence and is represented by spilites north of Melefan (figure 27), and by serpentines and spilites south of Destumi (figure 29). The third major stage occurs between the Sason flysch tongue and overlying upper red marl-clastic series of the Baykan group. Extensive lense-like serpentine masses at this stratigraphic level occur north of Ziyaret (figure 28). Spilites north of Dere and Beksi (figure 25) within the Sason-Baykan group, as well as spilites north of Hamzali and Lice within the Lice group belong to this stage (figures 23 and 24).

4. Conclusions and depositional history

Good correlation exists between the autochthonous Tertiary section and the allochthonous Sason-Baykan group at the Memla locality (figure 27). A proposed correlation is shown in figure 33. The lowermost red clastics correspond to the Antak formation. The buff biomicrite is equivalent to the Midyat limestones. The red sandstone correlates with the Germik evaporites and clastics and the black micrites with the Silvan algal limestone. The red and blue marls and overlying flysch sequence corresponds to the lower evaporite and upper clastic members of the Selmo formation. The thick red marl-clastic series above the flysch has no counterpart in the above southern autochthonous series except that there are lenses and layers of red sandstones and conglomerates (figure 24) within the uppermost Lice sediments. It indicates that the upper clastic series thin out rapidly towards the south.

Figure 34 illustrates the proposed correlated stratigraphic columns

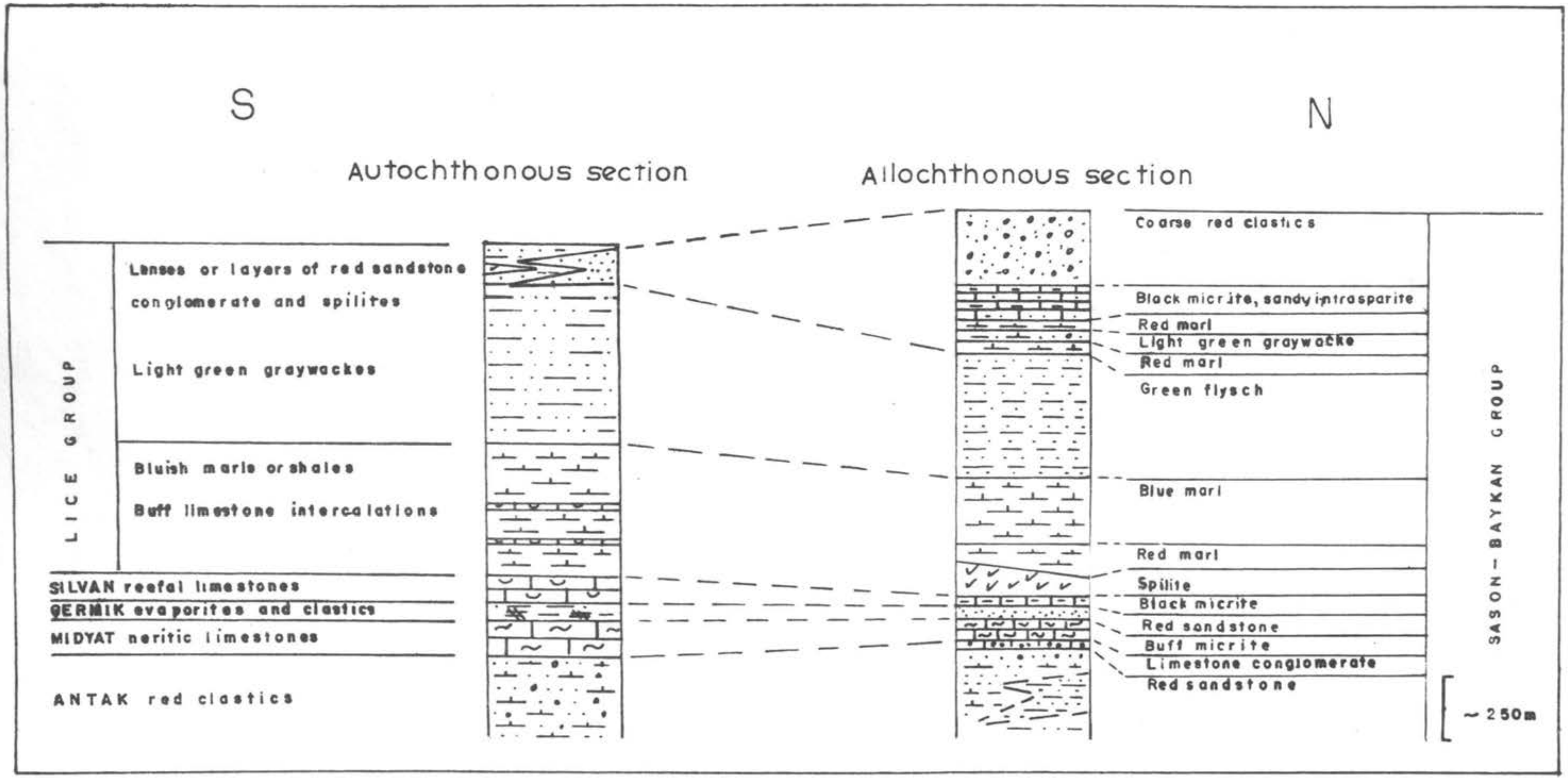

Figure 33. Correlation of autochthonous and allochthonous sections. The Lice group further correlates with the evaporites and sandstones of the Selmo formation in the south.

of the Sason-Baykan group. These columns were prepared from data in the sections already described except the section east of Minar. The Gemik section is based on drilling information. A regional northwest-southeast schematic stratigraphic correlation of the allochthonous Sason-Baykan group as bounded by the lower Lice sediments and an upper metamorphic tectonic plate is proposed in figure 35. The correlations are based on data from the stratigraphic diagrams of the preceeding figure. It is assumed that the Eocene marker horizon grades into pelagic limestone and that the marl and lower marl-clastic section wedges out northward while the flysch wedges out southeastward. This is suggested by the stratigraphic sections. It should be remembered that neritic Eocene biomicrite marker bed which is identical to the Midyat limestone is also present within or on the backdeep sediments. Thus a gradual facies change of Eocene biomicrite into pelagic limestone and the wedging out of the lower marl- clastic layer are local phenomena, even though they occur.

A schematic reconstruction of stratigraphic relationships across the geosyncline before the Late Miocene diastrophism is shown in figure 36. The facies and thickness changes from evaporite-red sandstone of the Germik and Selmo formations to calcareous marls shales and graywackes of the Lice group and then into marls and flysch of the Sason-Baykan group with intercalated spilites and serpentines indicate a gradual increase in depth of deposition and instability towards the north.

Evaporite deposition requires positive Eh, high pH, low energy, restricted circulation and an arid climate. Red and grey sandstones

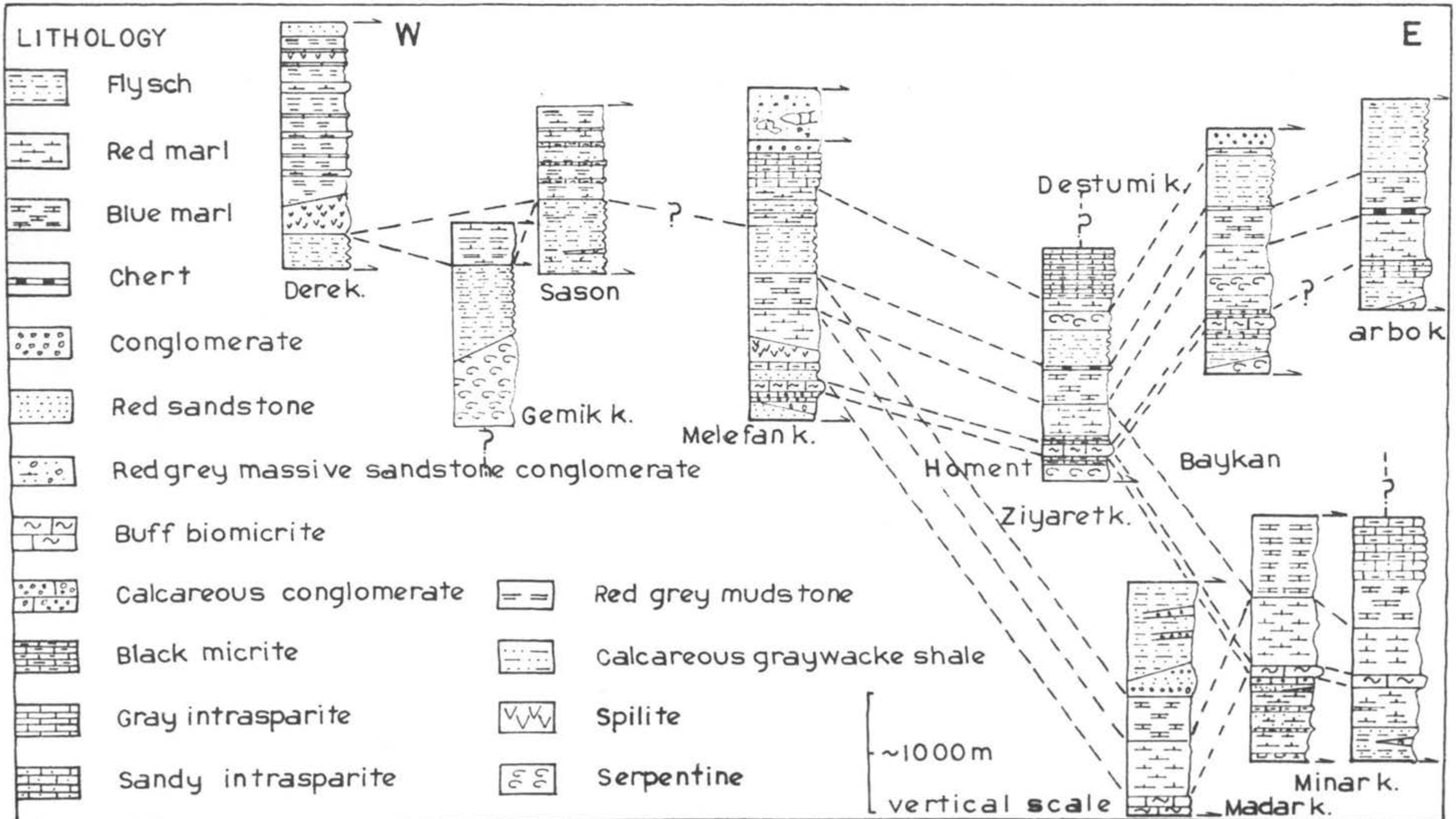

Figure 34. West to east stratigraphic columns of the allochthonous Sason-Baykan group.

accumulates under variable Eh, and pH conditions in transitional depths with a high supply and moderate to low subsidence rates. Fluctuations in Eh, which result in the red and grey sandstone alternation, may be related to variations in rate of supply/rate of subsidence ratio. Reef limestones are confined to littoral to infralittoral depths with high energy, high pH, positive Eh, and low rates of supply and subsidence. These set of tectono-environmental conditions occur in moderately stable marginal basins and hinge belts proximal to geosynclines.

The poorly stratified calcareous graywayckes, shales and marls with biomicrite intercalations were deposited in littoral to bathyal environments with negative Eh, low pH and moderate subsidence rate. Coarse calcareous graywackes were deposited under high rate of supply. These conditions occur on the moderately negative outer flanks of the geosyncline.

Black micrites and bluish marls with planktonic foraminifera such as Globigerina, and Globorotalia and also with Radiolaria accumulated in sublittoral to bathyal environments with low energy, high pH and commonly negative Eh. Rate of supply was low and rate of subsidence high. The origin of the red color of marls is controversial, but it must be partly related to the enrichment of sea water in iron and manganese from submarine volcanic activity. GARRISON and FISHER (1969) attribute the red color to the absence of bottom dwelling organisms in deep environments. The iron and manganese are oxidized during settlement. Due to absence of organic activity diagenetic reduction does not take place after depostion.

Flysch was deposited in similar bathyal environments when both the supply and subsidence rates were high. Turbidity currents are believed

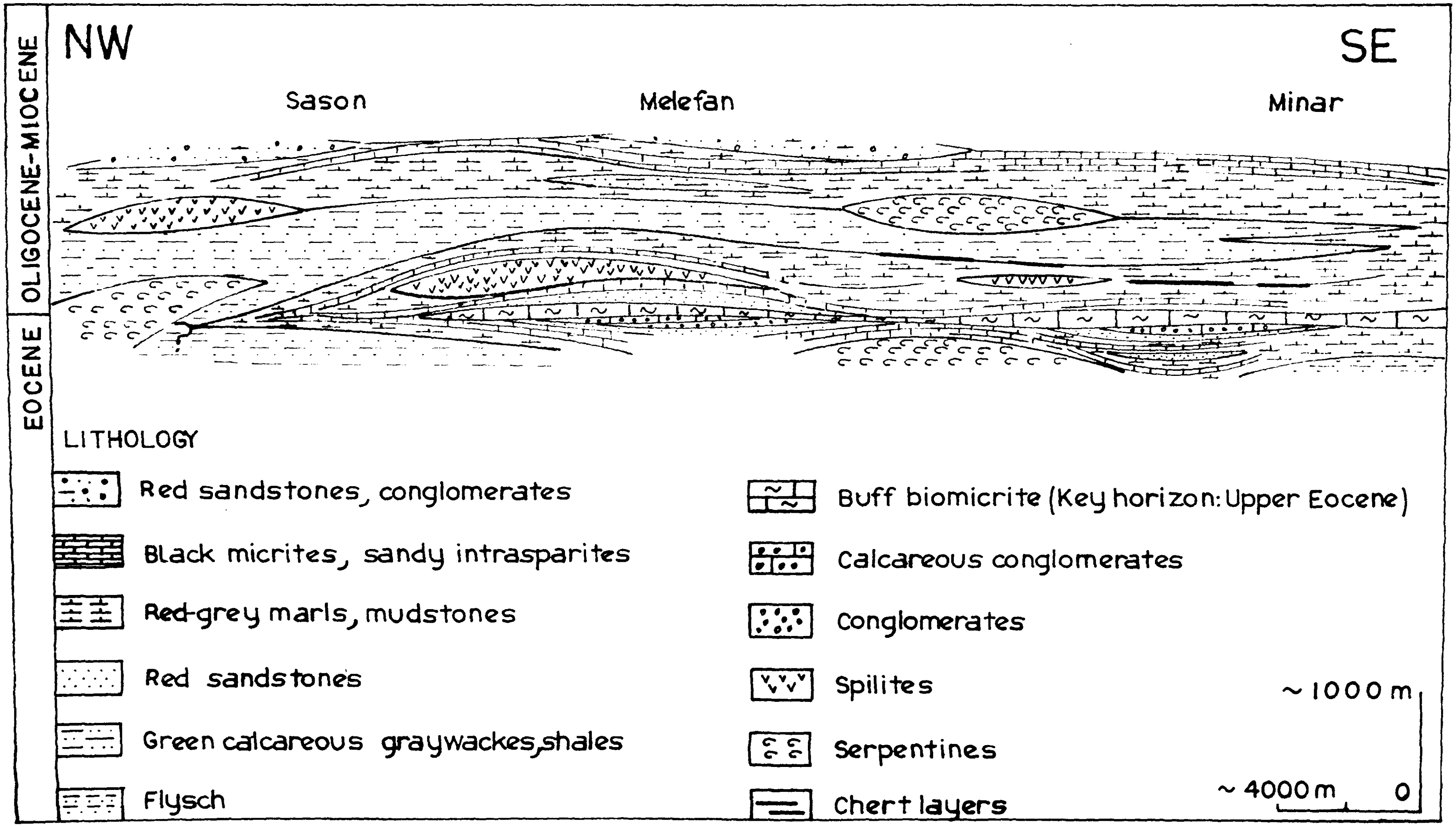

Figure 35. Regional stratigraphic diagram of the Sason-Baykan group based on correlation of stratigraphic columns in figure 34.

to be the cause of the transportation of coarse detritus to great depth, rhythmic deposition and graded-bedding. These conditions are characteristic of eugeosynclinal troughs. Accompanying submarine volcanic activity and serpentine occurrence and sedimentary stage gravity sliding are also characteristic of such unstable troughs.

The poorly stratified massive red conglomerates and sandstones were deposited in transitional depths under a high supply and low subsidence rate, under high energy, with positive Eh and high pH. These conditions are common on the inner flanks of a geosyncline adjacent to a rapidly uprising landmass.

Figure 37 illustrates the proposed stages of sedimentation from Cretaceous to Miocene in the area. After the deposition of the neritic Midyat limestone stable shelf conditions were replaced by geosynclinal conditions in the area. The northern backdeep region started to rise while a eugeosynclinal trough formed in front of the Bitlis massif. This trough was linked by a westnorthwest hinge belt to a marginal basin further south.

The post-Eocene depositional history of the area can be divided into an early subsidence and a later uplift period. The early subsidence period can further be subdivided into non-clastic and clastic stages. During the non-clastic stage, Globigerina and Globorotalia-bearing marls, micrites and chert, accompanied by basic volcanic activity, were deposited in the northern rapidly subsiding eugeosynclinal frontal trough. Shaly dolomitic evaporites with reef carbonates formed in the southern mildly subsiding marginal basin. After this non-clastic stage a major uplift occurred in the northern backdeep areas. Abundant sedimentary materials were supplied to the southern basin.

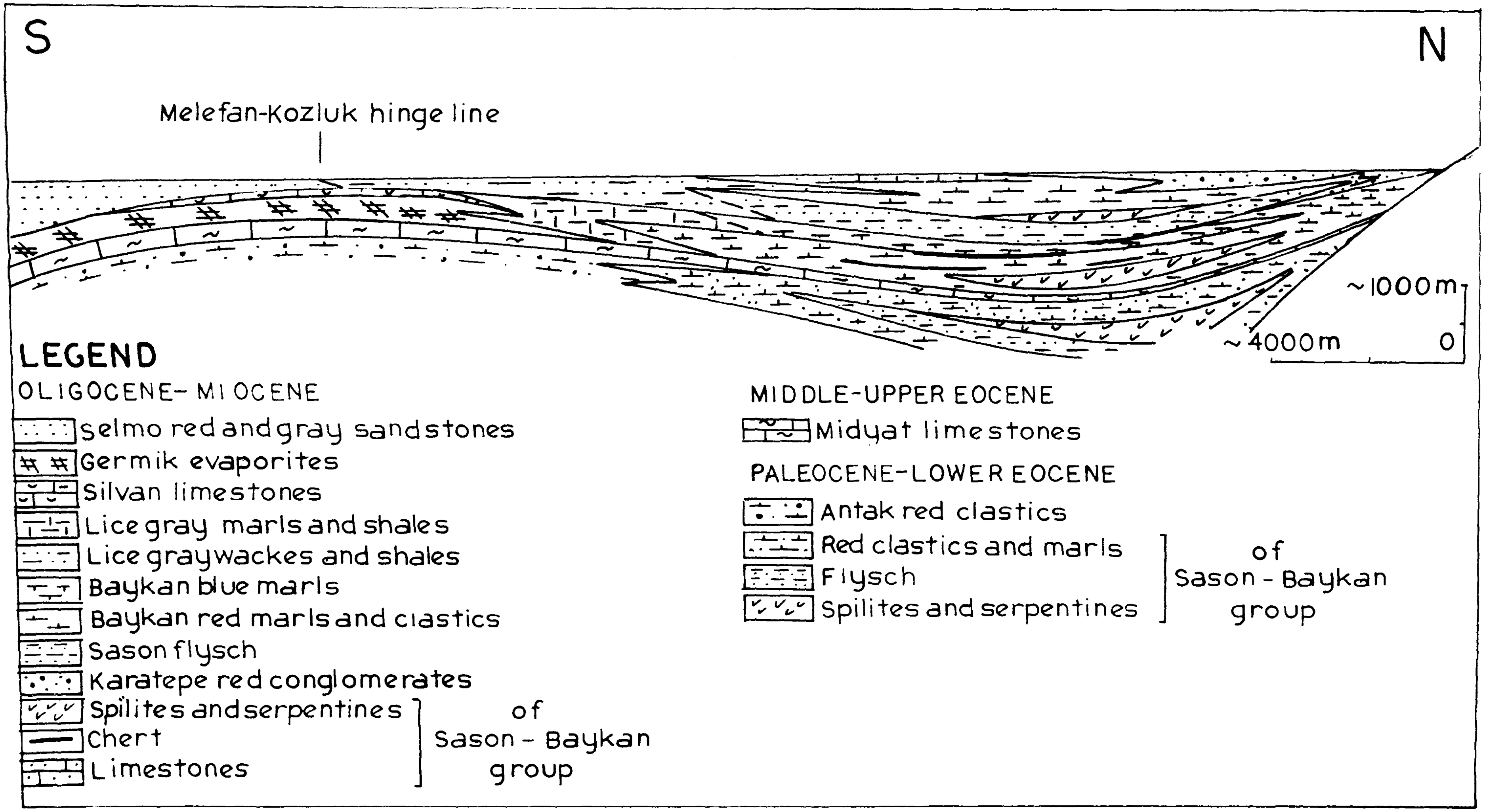

Figure 36. Schematic reconstruction of the stratigraphy of the Eocene-Miocene Lice-Baykan geosyncline illustrating the facies and tectono-environmental relationships.

Dark green graywackes-shales with graded bedding and exotic block were deposited in the northern troughs while subcontinental red and grey calcareous sandstones accumulated in the southern marginal basin. Rate of subsidence was higher or equal to rate of supply in this stage. The zone between the two basins had the least subsidence so that sediments which accumulated were relatively thin, shallow marine reef limestones and evaporites with calcareous sandstones. The transition from the northern eugeosynclinal troughs into the southern marginal basin is represented by poorly sorted calcareous graywackes shales and marls of the Lice group which were deposited on the outer flanks of the geosyncline proximal to the marginal basin. The Lice group constitutes a typical shallow burial graywacke association while the Sason-Baykan group represents a typical eugeosynclinal association.

During the final stages of the subsidence period the supply rate must have decreased. The flysch is locally covered by red marls with spilites and serpentines.

The next period marked a rapid uplift in the north with little or no corresponding subsidence in the south. During the final period, coarse red clastics filled the northern trough. Since uplift initiated in the north gradually affected deposition in the southern areas, the section transgressed towards south. The Sason flysch is slightly older than the upper graywacke and shales of the Lice group which is in turn slightly older than the Selmo red sandstones.

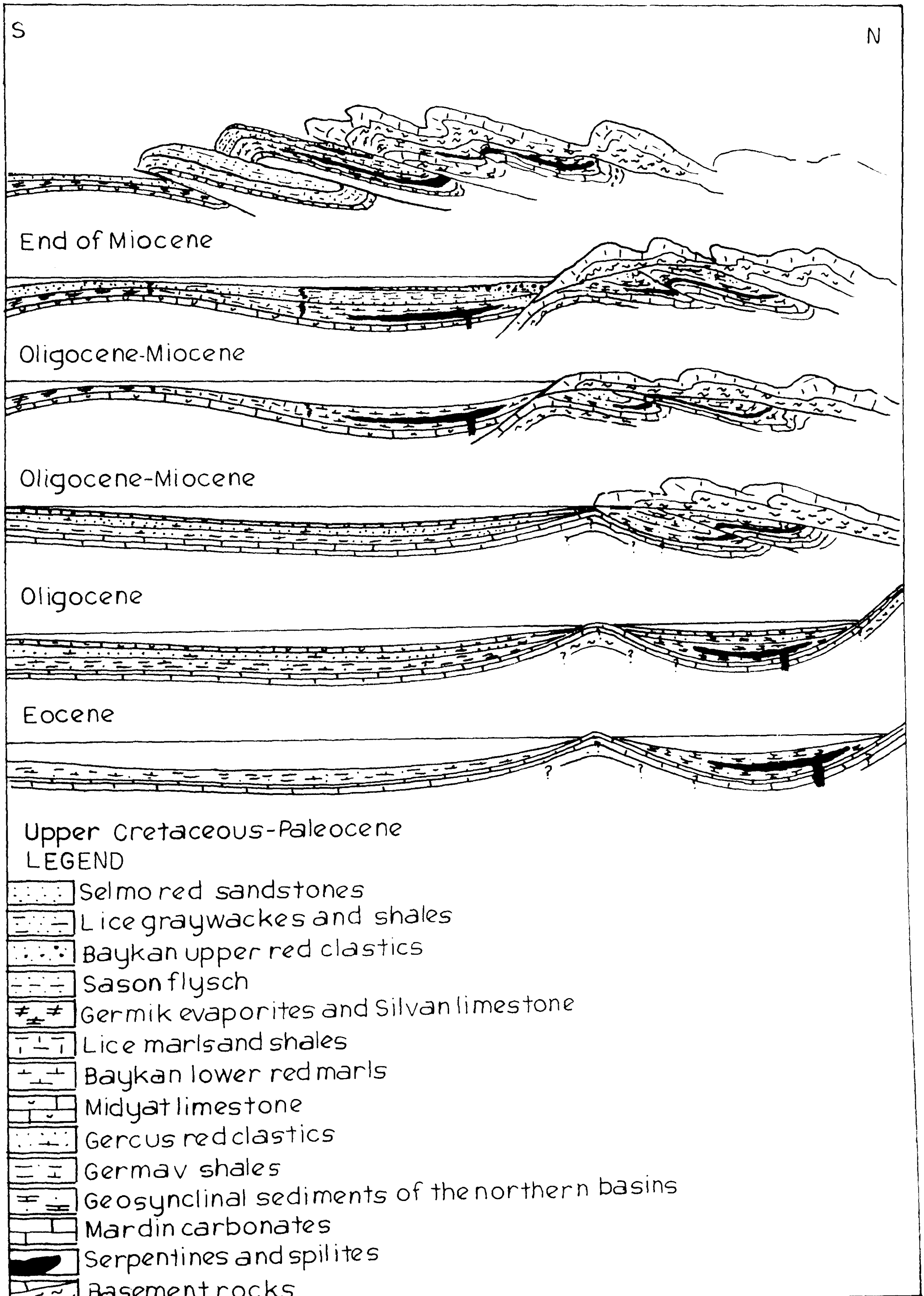

Figure 37. Proposed stages of sedimentation from Cretaceous to Miocene in the Sason-Baykan area.

V. STRUCTURAL AND TECTONIC ASPECTS OF THE AREA

A. Regional structural patterns

Folds and faults are the main structural elements of the Border-folds and overthrusts characterize the geosynclinal belt of south-east Turkey. The intensity of deformation increases gradually to the north as it approaches the orogenic zone.

Three types of folds and faults can be differentiated in the Borderfolds; 1) block faults and folds which are probably surface expression of basement swells and depressions, 2)surficial folds and reverse faults which do not correspond to basement uplifts but are the result of tangential stress from the north during orogenic cycles, 3) rejuvenated folds and faults. The first type folds occur mostly in the southern portion of the Borderfolds in the form of monoclines with steep southern flanks or as folds bounded by bifurcating faults on both sides. Tight asymmetric folds of second type with associated reverse faults on the southern flanks gradually replace open symmetrical folds toward the north. The rejuvenated folds and faults occur more frequently in the northern portions of the region.

A major thrust front extends from Iskenderun on the west to Hakkari on the east. This thrust front roughly coincides with the hinge line between the shelf area of the southern Borderfolds and the northern geosynclinal troughs. The metamorphic rocks of the Bitlis and Puturge Massifs, which constitue the hinterland of the basin, are thrust southward over the geosynclinal sediments. These in turn are thrust over the southern shelf deposits. The average horizontal movement of the metamorphic thrust plate is 15 kms. Displacement is more than 25 kms in the Sason area. The lower thrust sheet of geosynclinal sediments has an average of 10 kms horizontal displacement.

Although some transverse folds are present, the structures of both the Borderfolds and the northern geosynclinal belt follow the east-west Alpine trend and make a broad arch around the northward subsurface protrusion of the Arabian Shield in southeast Turkey. Although the shield rocks are not exposed in the region except in the Derik area, geophysical evidence indicate that they extend as a wedge as far as Karacadag just south of Diyarbakir. Folds and faults of the Borderfolds and northern thrust front gradually trend from northwest-southeast east of Diyarbakir to east-west and then to southwest-northeast to the west of Diyarbakir.

The first recognized phase of structural disturbance occurred at the end of Paleozoic. Resulting structures included broad regional swells such as the Mardin swell and Hazro-Maras swell (figure 3). Late Jurassic-Early Cretaceous epeiorogenic movements resulted dominantly in vertical block faulting. At this stage the Mardin swell probably developed into a prominent uplift bounded by faults on the south side. A third major cycle of deformation occured in Late Cretaceous. The Hazro swell acquired a dominant uplift characteristic at this stage. According to RIGHI and CORTESINI (1964), regional southward gravity sliding of eugeosycnlinal material onto shelf deposits took place during this stage. The main thrust faulting however, occurred at the end of Miocene and resulted in extensive southward movement of geosynclinal sediments and metamorphic rocks of the northern massifs. The results of this study suggest a possible early Oligocene thrust faulting to the north of the Sason-Baykan area before the Late Miocene orogeny.

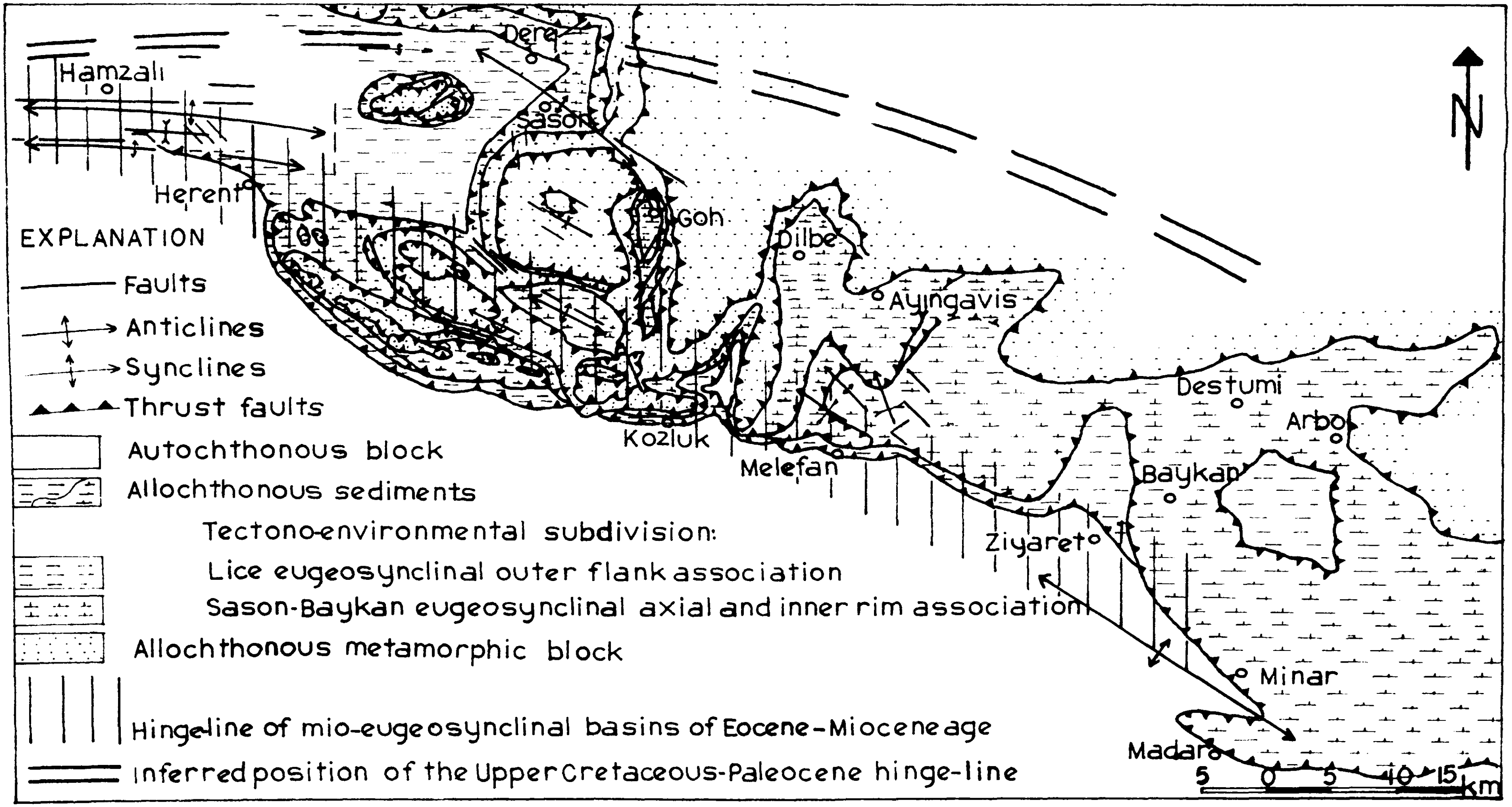

Figure 38. Generalized schematic tectonic map of the Hamzalı-Minar region including the Sason-Baykan mapped area.

B. Structures of Sason-Baykan area

The massive limestones and schists of the Bitlis Massif were thrust over the southern geosynclinal sediments at the end of the Miocene. The latter were in turn thrust over the marginal deposits as two imbricate slices.

West-to northwest-trending, large scale doubly plunging symmetrical or asymetrical folds, a conjugate set of northwest-northeast and a few major east-west trending faults are the main structural elements of the autochthonous block underlying the thrust sheets. Small-scale, tight, asymmetrical overturned folds, bedding plane, and break thrusts are characteristic of the allochthonous block of geosynclinal sediments. Except a few imbricate faults. steeply dipping faults and broad folds, there is little deformation within the uppermost thrust plate of the metamorphic rocks and massive limestones.

Structures of the autochthonous and allochthonous blocks are discussed separately.

1. Structures of the autochthonous block

The Golap and Belaso anticlines are the only major structures that crop out within the autochthonous block in the mapped area (plate 4). The northern Golap and southern Belaso anticlines trend east-west and are separated by an asymmetrical syncline.

The Golap anticline is a doubly plunging, symmetrical, open fold with 10-15 degrees dip on both flanks and with about 300 meters closure. The Belaso anticline is a tight asymmetrical fold with a vertical reverse faulted southern limb. This fold gradually overturns southward in the eastern part. The reverse fault along the southern flank develops into a break thrust near Herent (plate 3, figures 43 and 44). The Belaso structure becomes a step-like monocline with a steeply dipping faulted southern flank in its western part outside the mapped area.

The south flowing Batman river deeply dissects both the Golap and Belaso folds across the axes a few kms east of Hamzali and here forms a deep gorge. The red Antak clastics crop out in the fold cores. Midyat limestone, which covers the Antak formation is exposed as a topographic prominence barren of vegetation on the Golap anticline.

Broad anticlines plunge eastward under thrust cover south of Sason. The broad arching of the thrust plates in these areas, however, suggests the presence of the underlying structures along the continuation of the Golap and Belaso folds. Indeed, further east, outside of the mapped area, the Dodan and Tavan anticlines crop out under the thrust cover, south and southeast of Baykan (figure 38). This observation further substantiates existence of large scale structures within the autochthonous block under thrust sheets.

A smaller scale, northwest-trending, tight symmetrical doubly plunging anticline is present within the Lice graywackes west of Sason and is called the Sason anticline. The axis of the fold passes through Sason and the structure disappears under the thrust cover eastward. The overlying thrust plates are broadly arched, east of Sason and reflect the underlying Sason anticline (figure 45 and 46).

The thrust plates form another upwarp south of Sason around Maneran where a large fenster is exposed along the axial portion. This structure is approximately on the extension of the Golap anticline. A broad syncline separates the Sason and Maneran anticlines. The axis of this syncline passes through the Halkis Mountain (plate 2).

Figure 39. Selmo (I) fenster under massive limestones and calc-schists (2) in Pisyar valley, east of KOzluk, looking west. s. Sason thrust.

Figure 40. Allochthonous block, east of Sason, looking east. I)Lice group, 2)Sason-Baykan group, 3)quartzites, 4 and 6)calc-schists and crystalline limestones, 5)non-metamorphic sedimnets; graywackes and marls, b. Baykan thrust, s. Sason thrust, k. Kale thrust (units I to 19 of figure 26). Photo by P. D. Proctor.

The Selmo formation is overturned in front of the thrusts. This southward overturning can be followed from Herent, where the Belaso anticline develops into a break thrust, to east of Melefan.

A major east-west, longitudinal, normal dip-slip fault occurs along the axis of the Golap anticline. This fault extends more than 10 kms from west of Hamzali to north of Tanzi (plate 3). The fault plane dips 70-80 degrees to the north and the throw of the northern block is more than 100 meters (figures 43 and 44). A similar east-west normal fault occurs along the axis of the Belaso anticline. Besides these major faults a few other east-west, normal south or north dipping faults occur both on the Belaso and Golap anticlines (plate 3).

A number of parallel, northwest-trending transverse vertical faults occur on the Golap and Belaso structures. These are small-scale faults of _en echelon_ arrangement at some localities. Northwest-trending vertical faults are also common on the allochthonous block. Although less conspicuously developed, a conjugate set of northwest-trending vertical faults is also present (plates 2, 3 and 4).

Normal faults of north trend occur east of Taras (plate 2). Those mapped are upto 5 kms in length but are somewhat obscure because they occur within the homogeneous Lice graywackes.

Both the Midyat and Silvan limestones exposed in the axial portions of the Belaso and Golap anticlines are well jointed. Although the joints are somewhat irregular, two sets are recognized. A diagonal set has a northwest trend. The other set is perpendicular to the axis of the anticlines and is classified as a transverse joint set.

A slight unconformity between the Midyat limestone and overlying

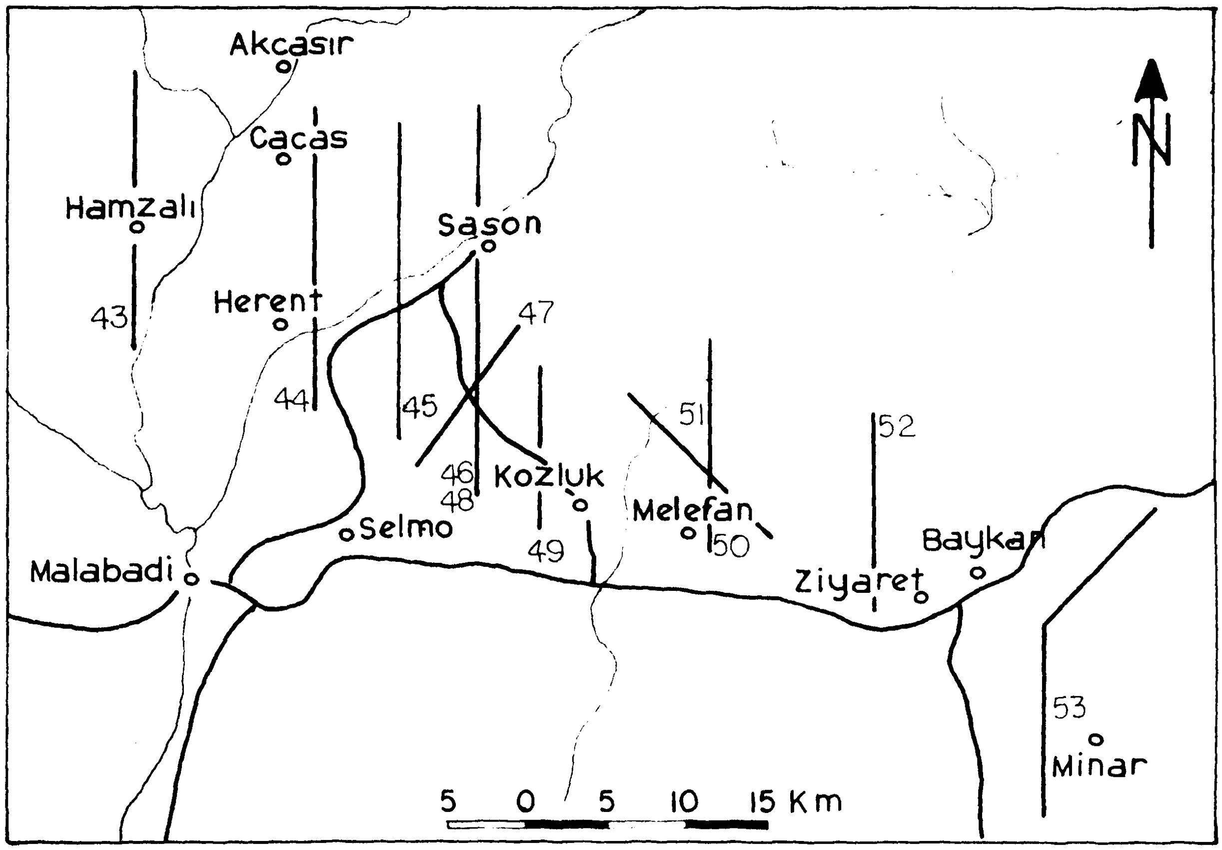

Figure 41. Index map of the geologic cross sections illustrated in figures 43 to 53.

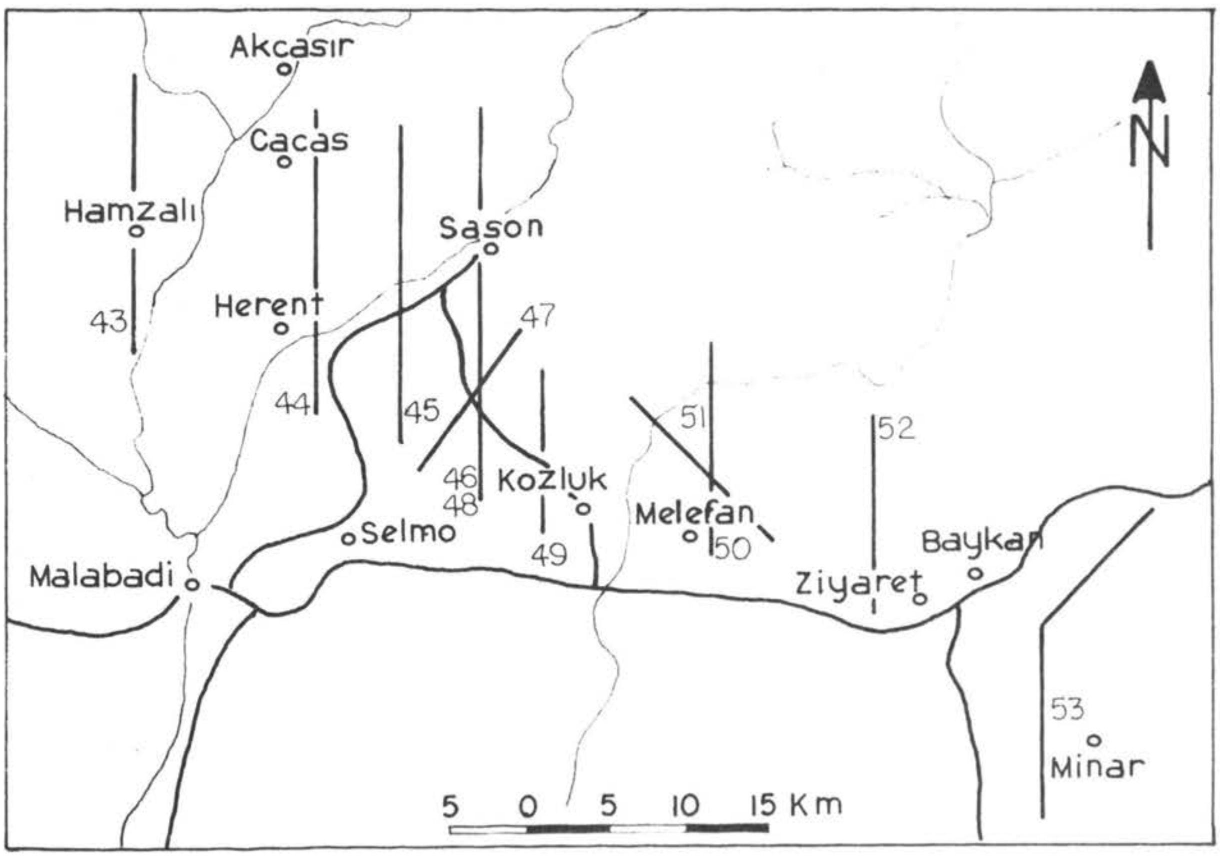

Figure 41. Index map of the geologic cross sections illustrated in figures 43 to 53.

Germik and Silvan formations on the Golap and Belaso anticlines indicates that these structures were already in existence in early Oligocene. The Belaso structure may have formed a step-like monocline at this stage. Both the Golap and Belaso structures constituted a part of the hinge belt during Oligocene-Miocene sedimentation.

Late Miocene diastrophism must have accentuated these structures and formed other smaller scale structures such as the Sason anticline. The Belaso structure developed into a break thrust in the east where the massive thrust plate of metamorphic rocks overrode this structure. Broad arching of the thrust plates suggest that folding continued after the thrusting was complete. Vertical and normal faults were the latest structures to form.

Dominantly vertical forces must have been responsible for the formation of the early uplifts and monoclines at the end of Eocene time. Subsequent accentuation of these earlier formed structures and developement of new folds resulted from horizontal compressional forces during Late Miocene orogeny. Such forces also caused extensive thrusting. The principle stress axis was oriented north-south. The east-west or northwest trends of the folds, presence of northwest-northeast conjugate sets of faults and north to south thrusting confirm this. A final stage of tensional stress resulted in normal east-west trending longitudinal faults.

2. Structures of the sedimentary thrust plate

The Lice group is displaced southward over the Selmo formation along the Lice thrust. The Sason-Baykan group is in turn thrust southward over the Lice group along the Baykan thrust. The Lice thrust is the lowermost of the four main thrusts in the area and has only a few kms displacement. The overlying Baykan thrust has more than 10 kms displacenet. The geosynclinal sediments of the lower plates underle the uppermost massive metamorphic thrust plate which moved more than 25 kms southward in the Sason-Kozluk area.

The Lice thrust begins as a break thrust near Herent on the eastern extension of the reverse fault of the overturned southern limb of the Belaso anticline (figure 44). The trace of this thrust fault between the simply overturned Selmo red and grey sandstones and the overlying drag-folded light green Lice graywackes and shales can be followed from Herent to as far as Ziyaret (figure 38). The Lice thrust is overriden by the Baykan thrusts east of Ziyaret where the Baykan group rests directly on the autochthonous Germik and Selmo red and grey sandstones (figure 30 and 38).

Both the Lice group and underlying Silvan, Germik and Midyat formation are thrust over the Selmo formation around Herent along the Lice thrust. The southward displacement of Midyat limestones probably does not exceed 1 km at this locality. The Lice graywackes and shales are, however, displaced more than 5 kms southward. This differential displacement may be the result of plastic flow of Lice shales under the moving plate of metamorphic rocks. There are, however, a number of imbricate thrusts of small displacement also partly responsible for this differential displacement. The imbricate thrusts are very difficult to map within the poorly stratified homogeneous and deformed Lice sediments. A few such thrusts, though are recognized north of Herent where the Silvan limestone is also involved (figure 44).

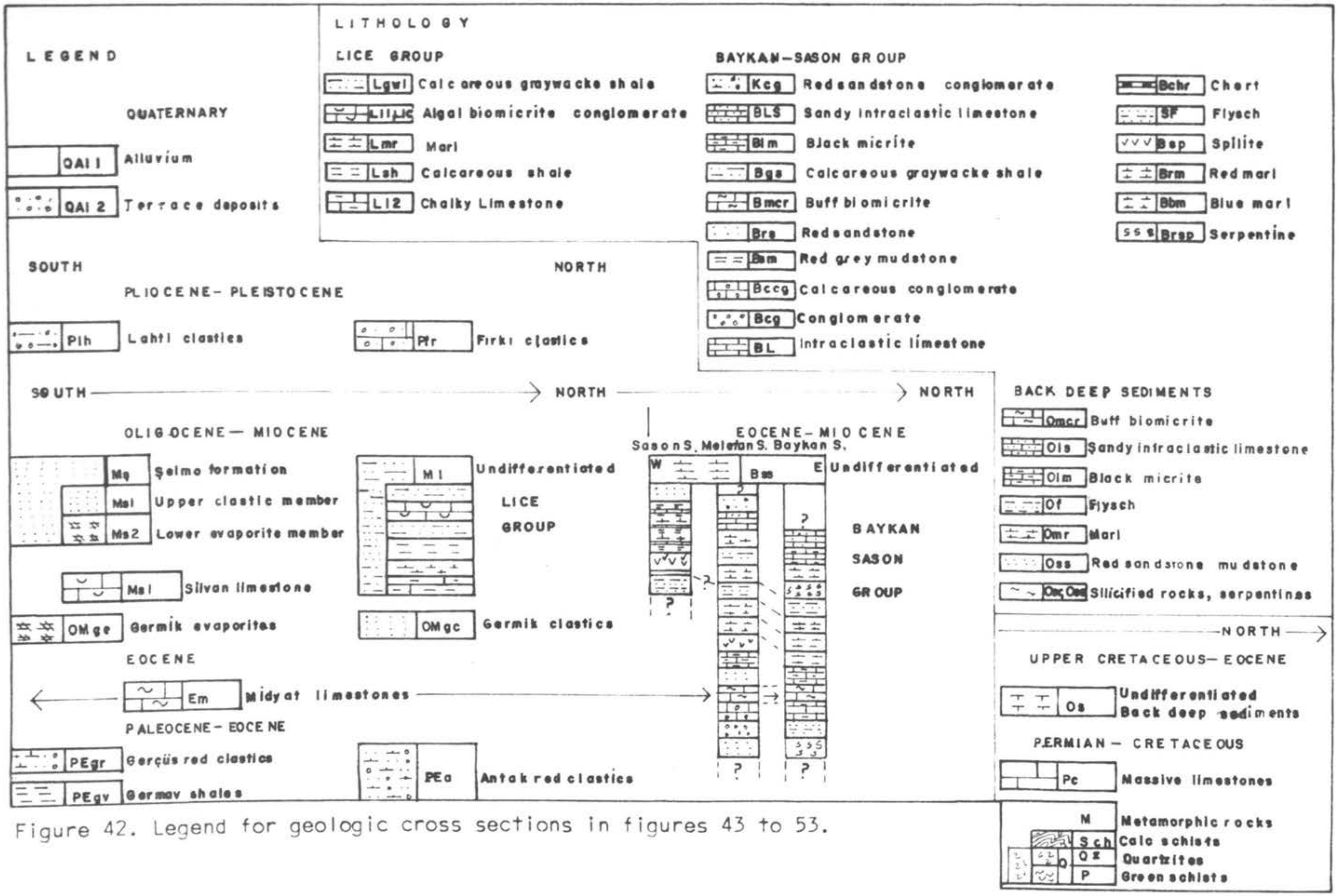

Figure 42. Legend for geologic cross sections in figures 43 to 53.

Further east around Melefan and Ziyaret, the Lice thrust fault cuts the stratigraphic section at a higher level. The Midyat limestones are not involved in this thrust faulting (figures 49, 50 and 52). The Selmo formation of the underlying autochthonous block forms a southward overturned disharmonic anticline in front of the Lice thrust south and southeast of Melefan (figures 50 and 52). The over-turning of the southern limb is observable south of Melefan. In Alicli and Yazpinar drill holes further north, normal succession of the Selmo formation was cut (OZDEMIR and OKTAY, 1968). Most probably drilling occurred on the northern flank of this overturned dis-harmonic anticline. The north dipping gypsiferous layers of the lower Selmo member, west of Ziyaret and outside the mapped area, is probably on the northern flank of this anticline. The plastic salts of the lower Selmo member may have aided in the development of this disharmonic fold under the overriding thrust plate of the Lice group.

The Baykan thrust fault is a horizontal break which crops out at about 1000 meters elevation. South displacement is estimated at 10 to 20 kms. The thrust fault is well exposed on the steep mountain sides north of Ziyaret, just outside the mapped area (figure 38). Here the Lice group occurs as uniform green graywackes and shales in a partial fenster (bounded by thrusts on three sides) under the colored Sason-Baykan sediments.

This thrust fault is also well exposed west and south of Sason where dark green flysch and upper red marl-clastics of the Baykan group are thrust over light green Lice graywackes. The Baykan thrust has been traced from Kulp on the west to east of Baykan (figure 38). While not mapped eastward, it should extend farther.

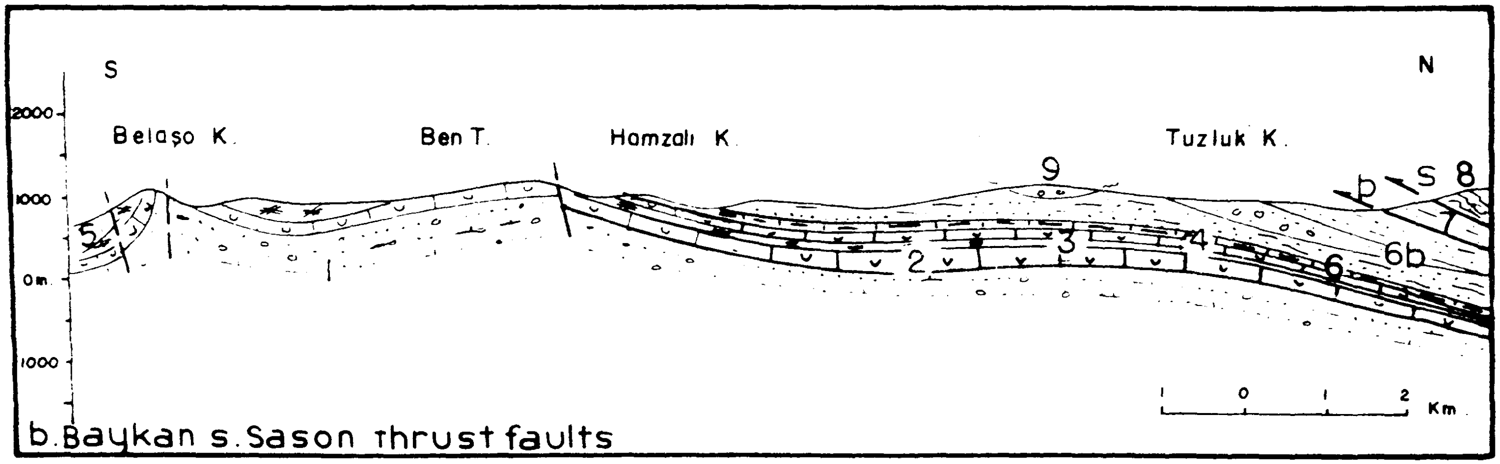

Figure 43. Section through Golap and Belaso anticlines, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Silvan limestone, 5)Selmo red sandstones, 6)Lice group, 7)Firki clastics, 8)Sason flysch, 9)metamorphic rocks.

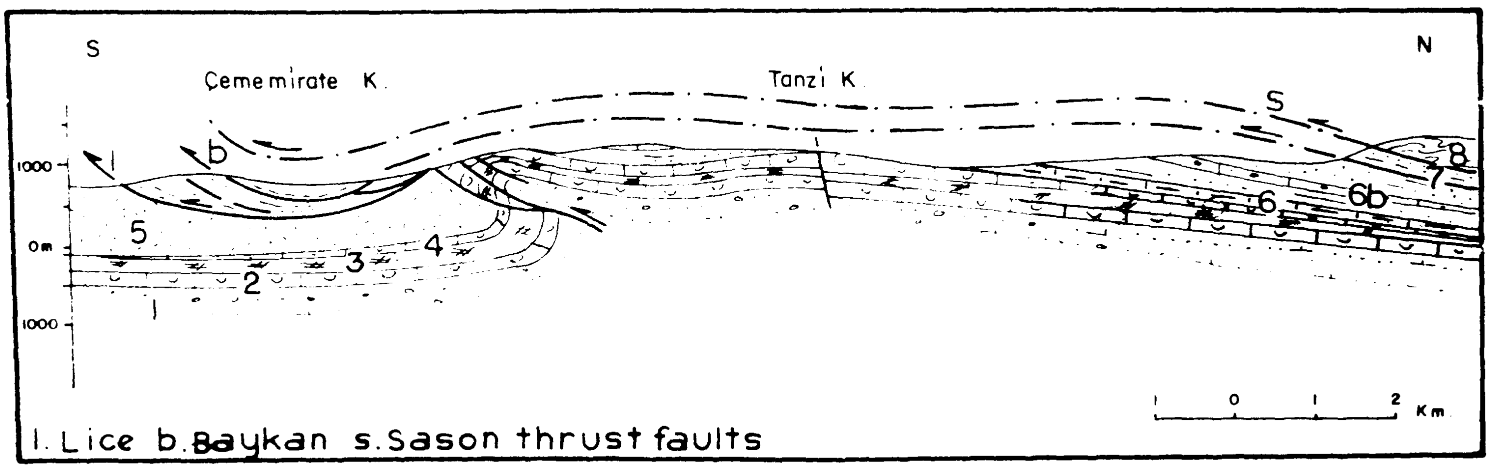

Figure 44. Section east of Herent, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Silvan limestone, 5)Selmo formation, 6)Lice group, 7)Sason flysch, 8) metamorphic rocks.

The Baykan thrust has been folded over the Dodan and Tavan anticlines south of Minar and outside of the mapped area (figure 38). Both the Baykan and overlying thrusts are also broadly folded over the Golap and Sason anticlines east and south of Sason (plate 2). Fenstern are recognized along the axial portions of the underlying anticlines. Hence both the undulation of the thrust planes and the locations of fenstern give good clues as to the structures in the underlying plate.

Tight folds and imbricate thrusts constitute the main structural elements within the intermediate sedimentary thrust plate. The thrust plate, as noted, also has broader folds imposed upon it from underlying fold structures. The Sason flysch usually exhibits drag folds under the metamorphic thrust plate. Such drag folds are best observed in the Sason flysch near Beksi and Dere and also around Manğik and Daraguzi west of Kozluk (plates 1 and 2). Upper Baykan red marl and clastic layer is also folded into a southward overturned syncline and thrust over the Sason flysch for a short distance north of Dere and Beksi.

A similar large scale southward overturned syncline is also present within the Baykan group south of Baykan just outside of the mapped area (figures 53 and 56). North of Melefan the Sason-Baykan group is broadly folded into two northwest trending open symmetrical synclines and an anticline (plate 4). In addition to the above major fold structures numerous small-scale folds occur within the allochthonous geosynclinal sediments. These folds generally parallel the thrust front, though local variances to the front are also present.

Two major thrusts faults occur within the allochthonous Sason-Baykan group north of Melefan (plate 4). The thick massive Karatepe conglomerates are thrust southward over the Sason-Baykan group. This

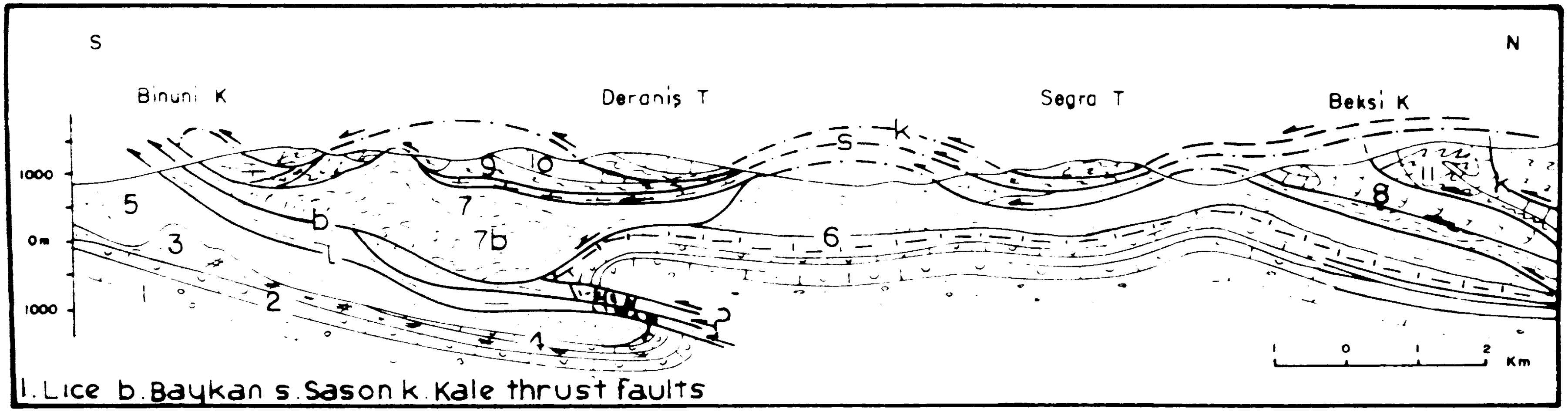

Figure 45. Section through Binuni and Beksi, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Silvan limestone, 5)Selmo red sandstones, 6)Lice group, 7)Sason flysch with serpentine (7b), 8)Baykan group, 9)quartzites, 10)crystalline limestones, 11)calc-schists.

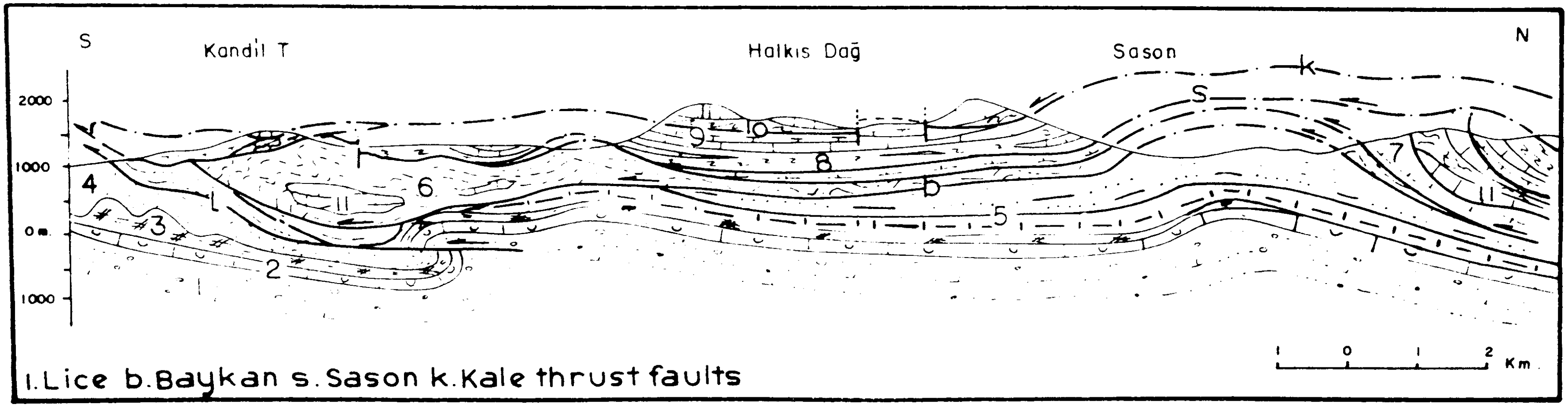

Figure 46. Section through Halkis Mountain and Kandil tepe, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Selmo red sandstone, 5)Lice group, 6)Sason flysch, 7)Baykan group, 8)quartzites 9)marls and graywackes of backdeep sediments, 10)calc-schists, 11)crystalline limestones.

thrust plane is also folded coincident with the underlying folds of the Sason-Baykan group (figures 50 and 51). Another thrust fault of southward displacement occurs at a lower stratigraphic level and a repetition of the Sason-Baykan section south of Ayingavis is the result of this thrust action (figure 50). A number of possible small imbricate thrusts occur within the Sason-Baykan group and Karatepe subgroup in the Melefan locality. Similar imbricate faults are also present within the Sason-Baykan group near Minar and Baykan outside of the mapped area (figure 53).

Vertical faults of northwest and northeast trend were mapped in the Melefan area (plate 4) within the Sason-Baykan group.

Several exotic gravity slide blocks have been recognized within the allochthonous geosynclinal sediments. The crystalline limestone blocks within geosynclinal sediments are easily identified due to the contrasting lithology of such blocks with the enclosing sediments. Examples of two enclosed exotic crystalline limestone masses at least 1 km long and 300-400 meters thick occur within the Sason-Baykan group north of Dere and Beksi (plate 2). A 400-meters thick limestone within flysch was cut in the Bolukkonak drilling. Surface mapping of the area (plate 1) suggestes that this limestone is most probably an exotic gravity slide mass similar to those which occur north of Dere and Beksi.

Finely crystalline medium-grey limestone of 1 to 2 kms size occurs as an isolated block within the Sason-Baykan group just east of Baykan and outside of the mapped area. This limestone mass was identified as an isolated block because no lithologic counterpart of this mass has been recognized elsewhere nor do the tight fold structures within this

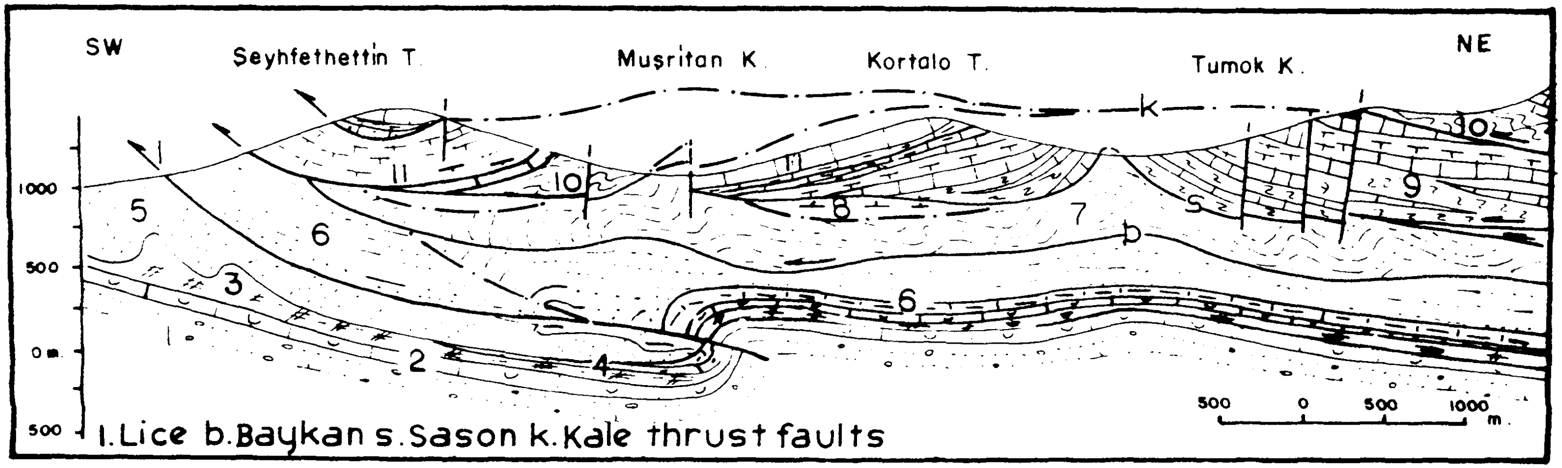

Figure 47. Section through Musritan, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Silvan limestone, 5)Selmo red sandstones, 6)Lice group, 7)Sason flysch, 8)Baykan group, 9)quartzites, 10)calc-schists, 11)backdeep sediments, 12)crystalline limestones.

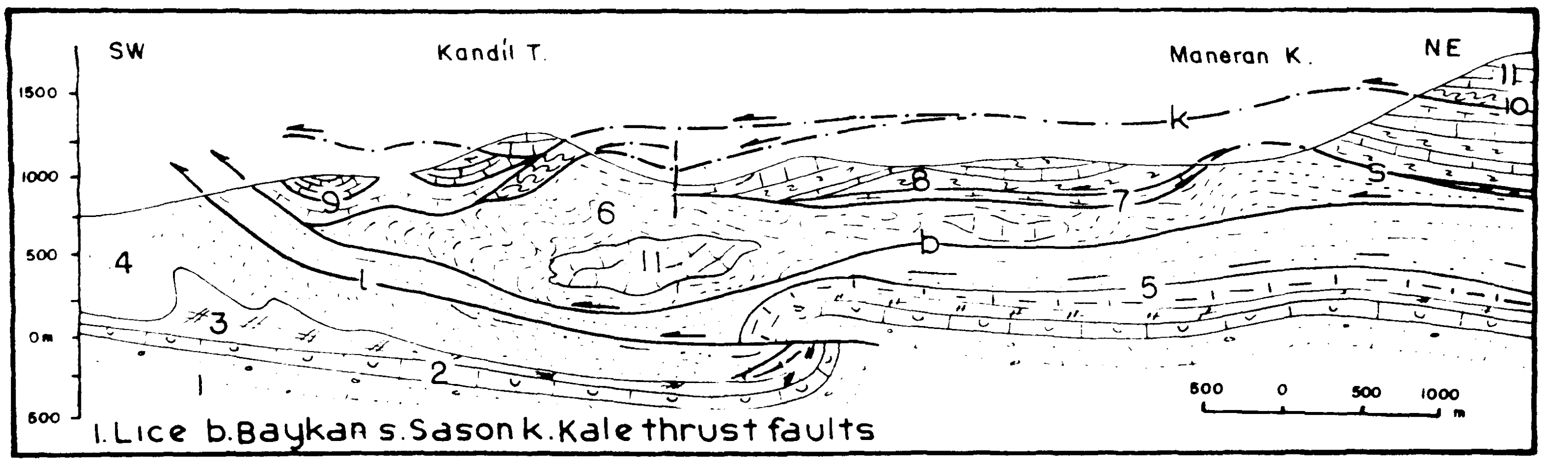

Figure 48. Section through Kandil tepe, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Selmo red sandstones, 5)Lice group, 6)Sason flysch, 7)Baykan group, 8)quartzites, 9)backdeep sediments, 10)calc-schists, 11)crystalline limestones.

limestone have projections into the enclosing sediments. The limestone mass may well be a gravity slide block of Upper Cretaceous-Paleocene sediments of the northern backdeeps.

Numerous other isolated crystalline limestone blocks varying in size from a few meters up to 500 meters occur within the Karatepe sub-group north of Melefan (plate 4). Small-sized isolated serpentine blocks occur along bedding planes within the Sason-Baykan group. These also represent slide blocks emplaced in their present position similar to the exotic limestone masses during sedimentation.

The boundary between the Sason flysch and overlying upper red marl-clastic layer of Baykan group is mapped as a thrust fault in the Sason-Kozluk area. This boundary is indeed tectonic at several localities such as north of Beksi, Dere, Maneran, and Mangik. However, due to intense deformation of the upper red marl-clastic layer of the Baykan group, it is not possible to disclose whether this boundary is a thrust everywhere.

3. Structures of the allochthonous massif

The massive crystalline limestones and metamorphic rocks are thrust southward along the horizontal to broadly undulating basal thrust over the geosynclinal sediments at about 1000-1300 meter elevation. The observable displacement is more than 20 kms (plates 1 and 2). Another major horizontal thrust fault occurs within the allochthonous massif at about the 1500-1700 meter elevation (figures 46, 47, 48, and 49). The well-defined lower basal thrust is exposed on the steep mountain sides and is called the Sason thrust. The upper thrust is best exposed on the western slopes of Kale Mountain and is called the Kale thrust (figure 40).

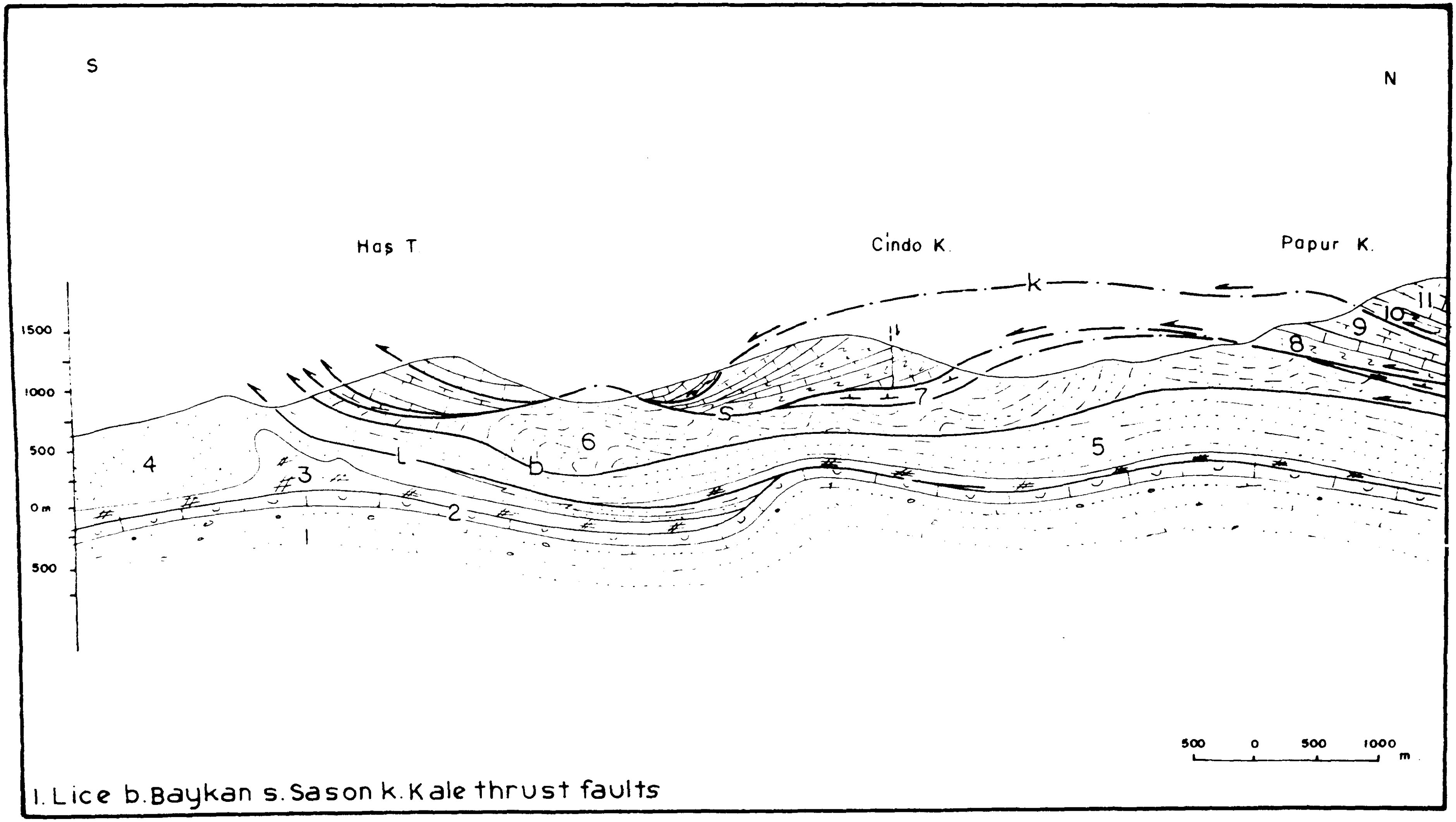

Figure 49. Section through Cindo, 1)Antak red clastics, 2)Midyat limestone, 3)Germik formation, 4)Selmo formation, 5)Lice group, 6)Sason flysch, 7)Baykan group, 8)quartzites, 9)backdeep sediments, 10)calc-schists, 11)crystalline limestones.

The thrust front generally trends northwest-southeast. However, the allochthonous massif extends southward as a protrusion of more than 15 kms into the Sason-Kozluk area. The different rock formations of the allochthonous massif are horizontal and parallel the Sason thrust. However, in the frontal portions of the thrust plate around the Gemik, Musritan, Cindo and Kozluk areas (plate I) superficial anticlines and synclines occur within this allochthonous massif. The superficial syncline between Has tepe and Cindo is a good example (figure 49). Several fenstern are exposed around Maneran, Harbak, Goh, Mangik and Pisyar areas (plates I and 2). Dark green Sason flysch crops outs within the fenstern except at the Pisyar fenster. Here the autochthonous Selmo formation is exposed (figure 39). Red marl-clastics of the Baykan group is also exposed as a thin, highly disturbed layer on Sason flysch under the metamorphic rocks in the fenstern (figures 39, 48, 49, and 57). Only one klippe of metamorphic rocks occurs west of Sason around Segra tepe (plate 2 and figure 45). This klippe is about 3 to 4 kms long and 2 to 3 kms wide. Metamorphic rocks and underlying Sason-Baykan flysch and marls rest on the Lice group.

The Kale thrust constitutes the upper boundary of the non-metamorphic sediments of backdeeps. The latter occur as a tectonic slice within the allochthonous massif. The quartzite-calc-schist-crystalline limestone sequence of the basement was thrust over back-deep marls and flysch prior to the time the whole massif was displaced southward on the Sason thrust. The earlier formed Kale thrust is involved in the superficial folding of the rocks of the allochthonous plate.

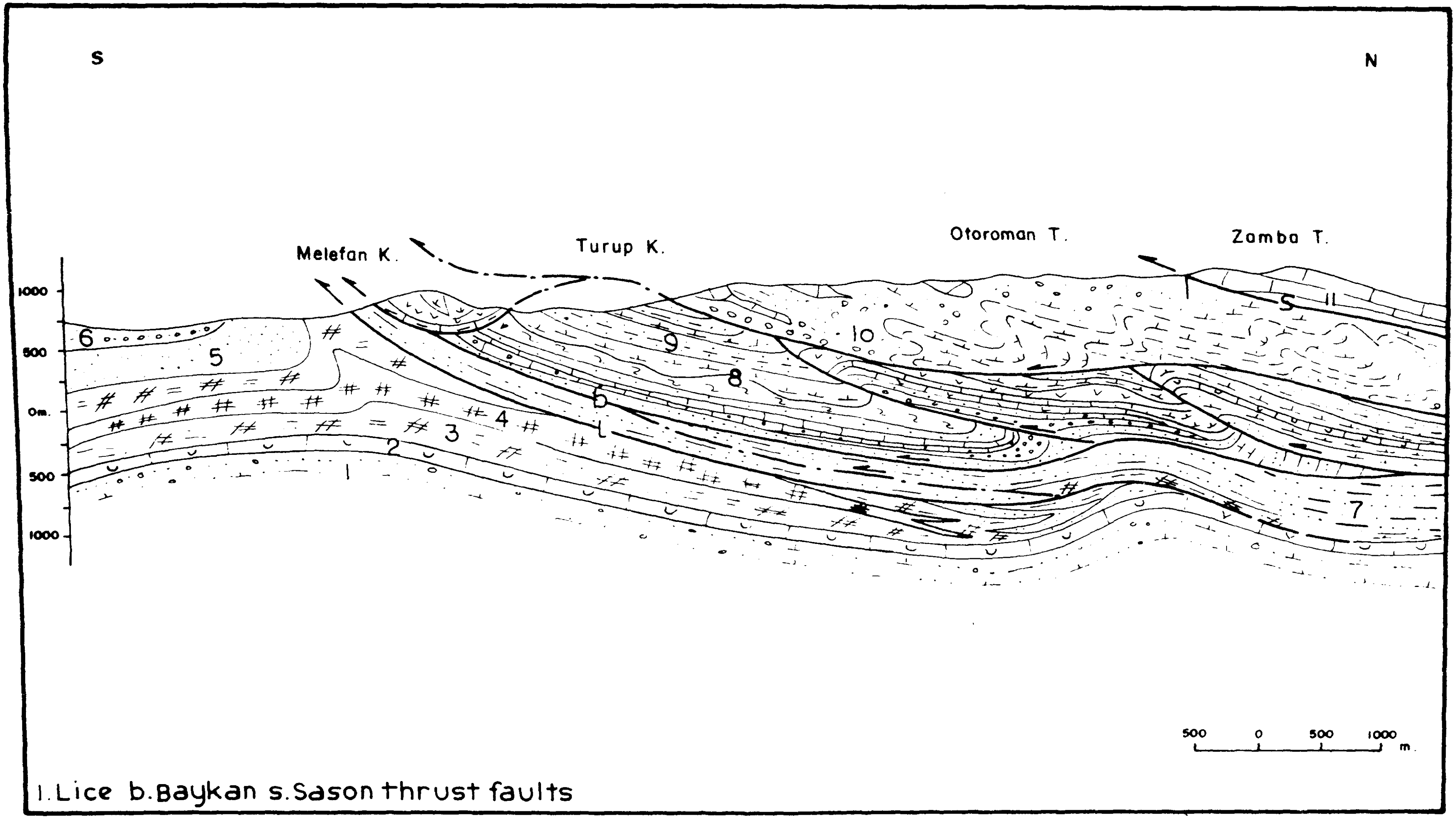

Figure 50. Section east of Melefan, 1)Antak red clastics, 2)Midyat limestone, 3)evaporites of Germik and Selmo formations, 4)salts of lower Selmo member, 5)red sandstones of upper Selmo member, 6)Lahti clastics, 7)Lice group, 8)Baykan group with Sason flysch tongue (9), 10)Karatepe subgroup, 11) crystalline limestones.

The upper rock sequence of the allochthonous massif consists of greenschists and quartzites-calc-schists and crystalline limestones-non-metamorphic marls and flysch- and uppermost calc-schist and crystalline limestones. This succession is fairly consistent throughout the Sason-Kozluk area. There are, however, local variations due to wedging or imbrication, therefore major variations in the sequence deserve special attention. A reverse succession occurs north of Sason, around Kuringis, Halilan and Dagana (plate 2), as a lower mirror image of the upper normal sequence. The latter occurs east of Sason, Cagut and Badramut (plate 2). The upper normal sequence of the massif dips gently northward while the lower reverse sequence is steeply inclined north, south, or vertical. This may be the result of imbricate thrust faulting. Yet, it is difficult to account for the vertical or southward dips of the beds in the lower plate by a north to south imbrication. An alternate explanation is the presence of a break thrusted overturned fold. The lower reversed sequence would then correspond to the lower limb of the fold. Since the reverse sequence is not observed anywhere south of Sason, it would require that the upper limb travel 20 kms southward along a break thrust in the axial plane of the overturned fold structure in the Sason-Kozluk area. The tongue like southward protrusion of the allochthonous massif in this area would then represent the displaced upper limb of such a fold. The Sason basal thrust fault would be a break thrust in the axial plane of this fold.

Two tectonic slices of unmetamorphosed sedimentary rocks, instead of one, occur within the south dipping metamorphic rocks of the allochthonous massif. The first layer crops out on the northern slope

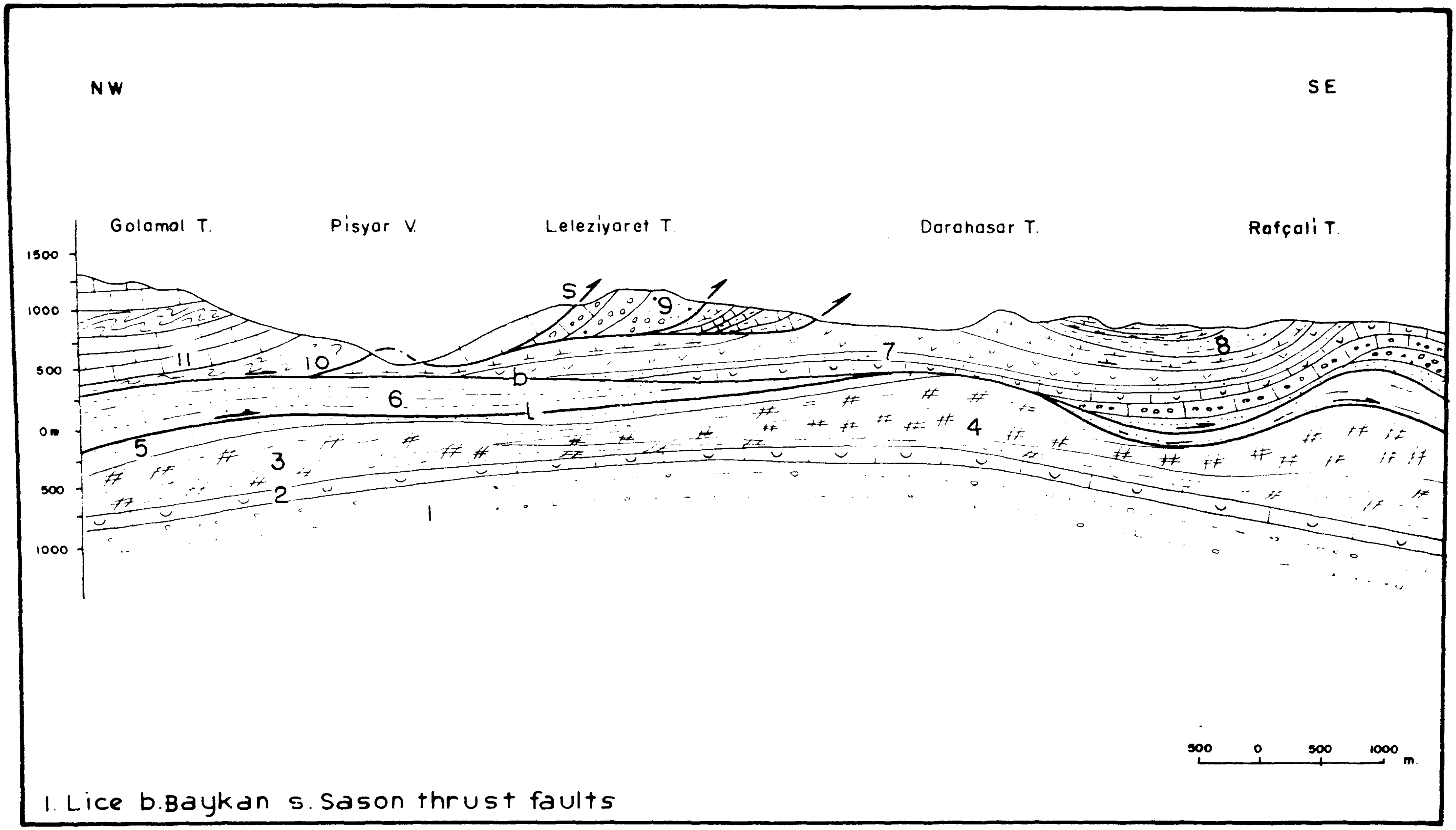

Figure 51. Section north of Melefan, 1)Antak red clastics, 2)Midyat limestone, 3)evaporites of Germik and Selmo formations, 4)salts of lower Selmo member, 5)red sandstones of upper Selmo member, 6)Lice group, 7)Baykan group with serpentines, 8)crystalline limestones.

of Kortalo tepe, south of Tumok village. This slice belongs to the Upper Cretaceous-Paleocene backdeep sediments. The upper slice of sediments crop out south of Musritan (figure 52). These sediments consist of red marls, mudstones, black micrites and intraclastic limestones with spilite layers. They overlie calc-schists on the northern slopes of Seyhfethettin and Kandil tepe. The calc-schists in turn overlie the lower sedimentary slice on Kortalo tepe (plate I and 2).

Whether this upper slice of sediments belongs to the backdeep group or the Eocene-Miocene Sason-Baykan group has a direct bearing on the structural interpretation of the area. Fossil determinations to date have not been conclusive. If the sediments of the upper tectonic slice belong to the Baykan group which was deposited in the frontal trough during Oligocene-Miocene times, then it is necessary to conclude that the Kale thrust formed in early Oligocene time and not during the late Miocene orogeny or that underthrusting occurred in the area.

The boundary between these sediments and the underlying calc-schists appears to be of normal depositional type rather than a thrust fault in the Musritan area. There is no surface indication of underthrusting in this area. It is also difficult to visualize south dipping reverse faults forming under north to south stress and thin cover.

Although underthrusting was suggested by OZDEMIR and OKTAY (1968) to explain the 400 meters-thick limestone encountered in the Bolukkonak drilling within the Sason flysch, absence of supporting field evidence weakens this possibility. This limestone is most probably an exotic gravity slide block (figure 48).

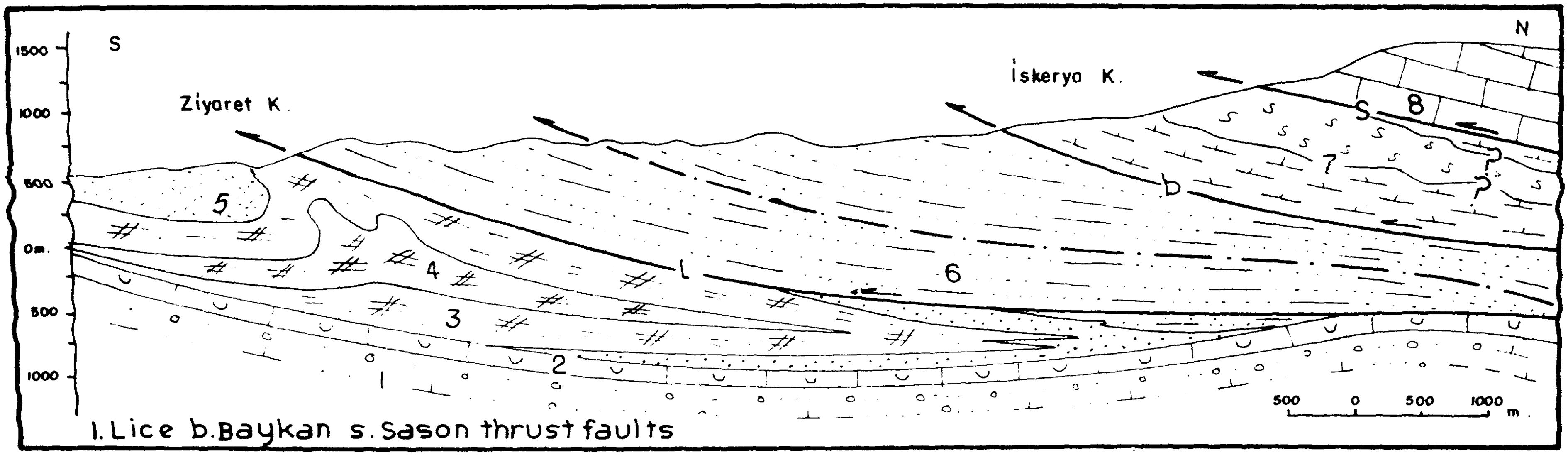

Figure 52. Section through Ziyaret, 1)Antak red clastics, 2)Midyat limestone, 3)evaporites of Germik and Selmo formations, 4)salts of lower Selmo member, 5)red sandstones of upper Selmo member, 6)Lice group, 7)Baykan group with serpentines, 8)crystalline limestones.

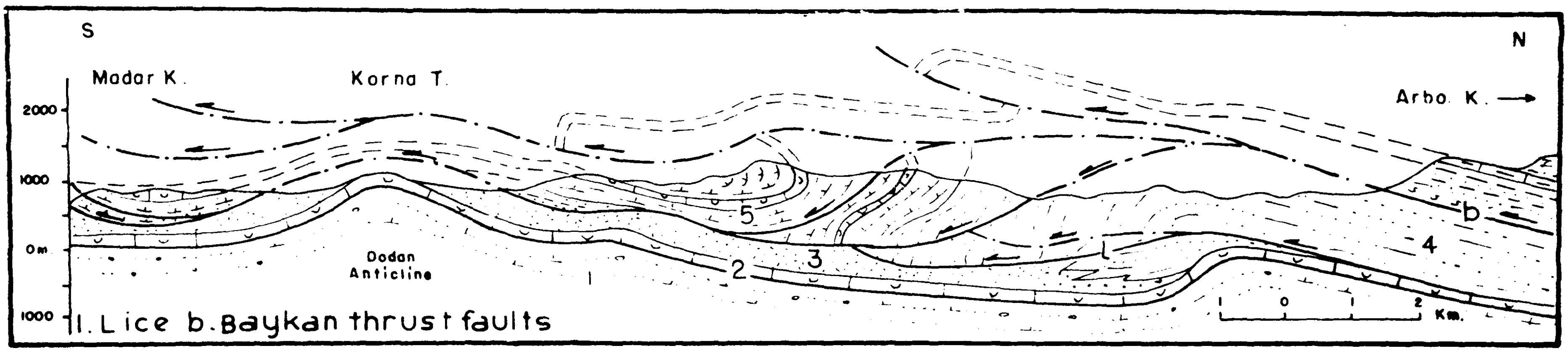

Figure 53. Schematic section through Arbo and Madar, 1)Antak red clastics, 2)Midyat limestone, 3)red sandstones of Germik and Selmo formations, 4)Lice group, 5)Baykan group.

An alternate explanation is illustrated in figure 54. The Kale thrust must have formed after the deposition of Eocene shallow marine limestones. These apparently constitute the uppermost layer of backdeep sediments. The metamorphic rocks and massive limestones were thrust over the backdeep sediments. The southern portions of the thrust fault area must have subsequently undergone subsidence and the Sason-Baykan frontal trough sediments were deposited on the metamorphic rocks which constituted the northern flank of the basin during Oligocene-Miocene times. Late Miocene orogeny caused southward displacement of the metamorphic massif along the Sason thrust.

On the other hand, if both of the tectonic slices of sedimentary rocks within the metamorphic rocks in the Musritan-Kortalo area belong to the Upper Cretaceous-Eocene backdeep sediments then it is possible to explain the structure of the region with only one stage of diastrophism at the end of Miocene. This explanation is illustrated in figure 55. In such a case repetition of the tectonic slice of backdeep sediments may be the result of secondary imbrication.

Although an overturned fold structure is believed to exist in the Sason area, no indication of a nappe structure was observed east and west of the mapped area in the Baykan and Kulp regions.

Steeply inclined faults are not common in the allochthonous block, though there is a set of northwest trending vertical faults west of Tumok, and northeast trending set in the vicinity of Harbak and Goh. A few northwest-trending vertical faults also occur near Musritan. Such faults appear to parallel the axial trace of underlying fold structures. A number of north-south trending normal faults occur on the northern slopes of Halkis Mountain, and also south of Kuringis. A few east-west trending faults have also beeen recorded. These vertical normal faults are later than the thrust faulting.

Foliation is well developed in the green schists and calc-schists of the upper plate. Foliation is due to both orientation of flaky minerals and shear cleavage.

Massive limestones are intensely jointed. Although joints are irregular three prominent sets may be recognized. The flat-lying set may be bedding joints or planes. The other two sets should then be strike and dip joints. However, field measurements of the trends of the joint planes indicate no consistent direction.

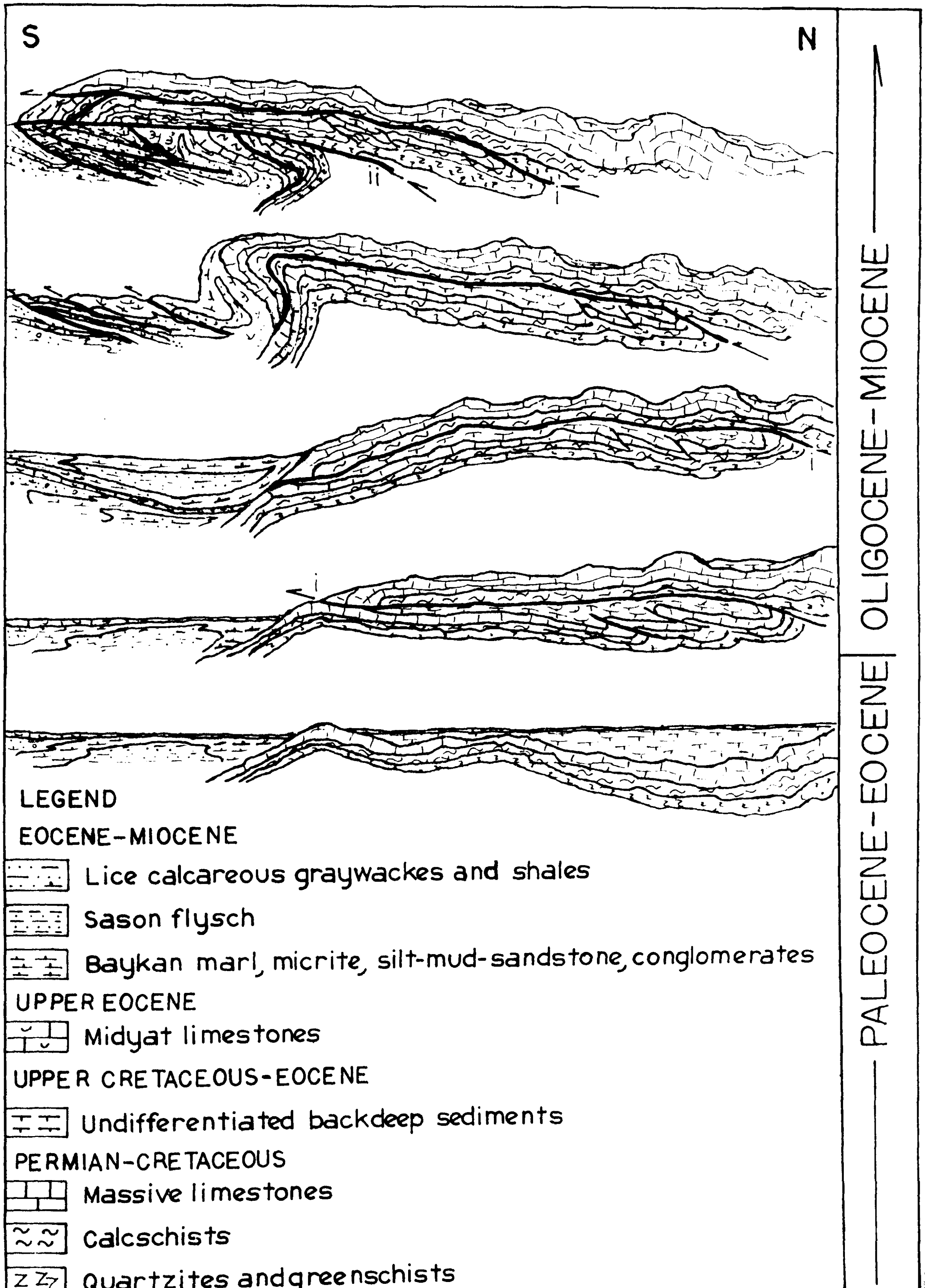

Figure 54. Schematic diagram of structural evolution of the Sason-Baykan area. i. Kale thrust, ii. Sason thrust.

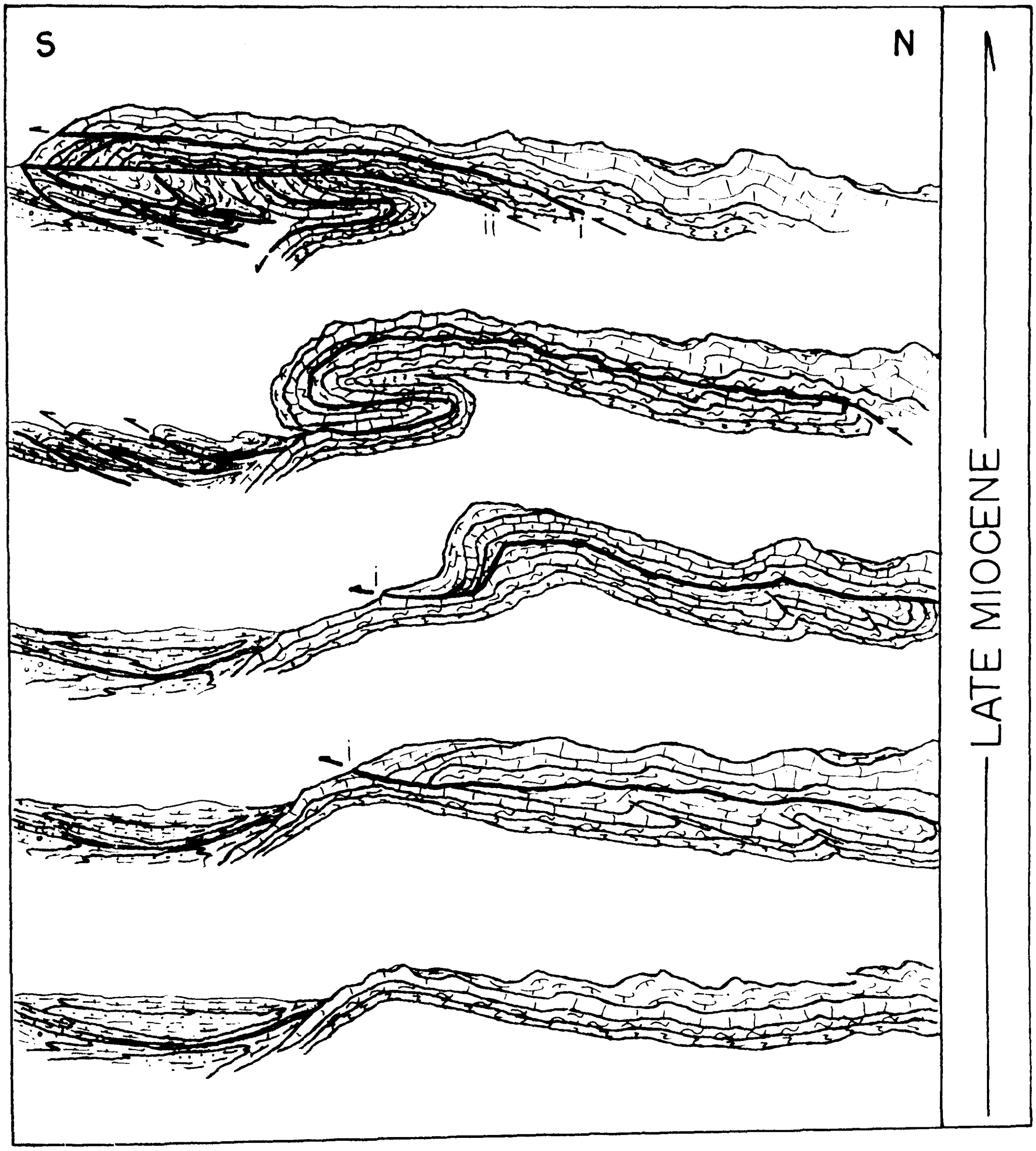

Figure 55. Alternate interpretation of structural evolution of area of figure 54. Both Kale and Sason thrusts formed during the Late Miocene diastrophism.

VI. PETROLEUM IMPLICATIONS IN THE AREA

A. Petroleum geology of southeast Turkey

Southeast Turkey is in the northern portion of the Middle East Mesozoic and Tertiary marginal basin where prolific oil fields occur in Iran, Iraq and Saudi Arabia. This marginal basin between the Arabian Shield and the northern eugeosynclinal belt is divided into stable and unstable shelf zones from south to north. The stable shelf extends from eastern Saudi Arabia through southwestern Iraq into Syria. The unstable shelf extends from western Iran, through northernmost Iraq into the northern part of the southeast Turkey (figure 60).

Though suitable reservoir rocks and abundant trap possibilities are present and there is similarity to the extensive oil bearing structures in Iran and Iraq, such oil fields have not been found in southeast Turkey. Several factors may account for this unfavorable situation. Two major uplifts, one at the end of Jurassic and another at the end of Tertiary, severely reduced the oil potential in the area.

The major uplift which occurred at the end of Jurassic resulted in deep erosion of potential hydrocarbon-bearing sediments and escape of pre-Jurassic accumulations. While prolific source beds were being deposited in the deep sea environments in the southern areas of Iran and Iraq, southeast Turkey remained above sea level or under shallow water conditions throughout Mesozoic time. The shallow water Mardin carbonates of Lower-Middle Cretaceous are the time equivalent of the deep sea sediments of the northern Iraq which are believed to have acted as the main source rock in the area.

Figure 56. Overturned syncline within the allochthonous Baykan group, south of Baykan, east of Minar, looking northwest.

Figure 57. Thrust faults and Maneran fenster, south of Halkis Mountain, looking north. 1)Sason flysch, 2)quartzites, 3, 5 and 6)calc-schists and crystalline limestones, 4)non-metamorphic backdeep sediments; red marls, s. Sason thrust, k. Kale thrust.

Uplift at the end of Tertiary was far more pronounced in southeast Turkey. The Tertiary evaporites, which acted as an effective cap rock in Iran and Iraq were deeply eroded in Turkey exposing the reservoir rocks of Tertiary and Mesozic times. The Midyat limestones, which are time equivalent to the productive Asmari limestone in Iran, are exposed at the surface in southeast Turkey.

In addition to deep erosion of cap rocks, severe deformation near the orogenic belt caused intense fracturing of Lower Tertiary marly formations and reduced the ability of such semi-plastic formations to act as cap rocks. These factors resulted in extensive flushing of potential oil fields.

Examples of productive fields such as the Raman field with heavy asphaltic oil along with fresh or slightly brackish water, suggest that heavy oil is a remnant in a partially flushed field. Several other prospective traps were found completely flushed. Only oil fields which were effectively sealed against free circulation of ground water prevented the escape of of oil. These traps produce light oil underlain by salt water. The Garzan field is an example. Here light oil interfaced. with salt water is produced from lense-like reef carbonates in shale.

Neither the Foothills thrust belt nor the orogenic zone to the north parallel the northern boundary of the Arabian Shield. These linear features extend roughly east-northeast while the Arabian Shield protrudes northward as a subsurface tongue into southeast Turkey. The width of the basin, the stable and unstable shelf zones and the eugeosynclinal troughs narrow westward as they enter southeast Turkey from Iran. In the western parts of southeast Turkey the thrust belt is almost tangential to the northernmost subsurface nose of the Arabian

Figure 58. View of thrusts north of Gemik, looking east. 1)Lice gryawackes and shales, 2)Baykan red marls, 3) crystalline limestones, b. Baykan thrust, s. Sason thrust. Photo by P. D. Proctor.

Figure 59. View of thrusts north of Kulp, west of the mapped area. 1)Lice graywackes, 2)serpentines and spilites, 3)metamorphic rocks, t. thrusts.

Shield.

The hinge line between the unstable shelf and the northern troughs is far south of the thrust belt in Iran and eastern Iraq and therefore is not affected by the orogenic activity to the north. Most of the important oil fields in western Iran and eastern Iraq occur along this hinge belt between the northern troughs and the southern unstable shelf zone. Source rocks of the petroleum are believed to be the euxinic geosynclinal sediments which were deposited in the northern troughs. The oil migrated southward into suitable reservoir rocks of Tertiary age, namely the Asmari limestone which is capped by the Fars evaporites in Iran.

In southeast Turkey the hinge line is very close to the thrust belt. In the western part of southeast Turkey it is actually involved in the thrust zones. Thus, in contrast to the unaffected source and reservoir rocks in western Iran, both the potential petroleum sources in the northern geosynclinal sediments and the reservoir rocks are much distrubed in southeast Turkey. Because the troughs and basins are also much narrower in southeast Turkey, the volume of deposited source rocks is much smaller. Yet, notwithstanding the unfavorable factors noted, some of the most productive oil fields in southeast Turkey such as the Selmo and Diyarbakir fields are situated in the vicinity of this hinge belt.

Upper Cretaceous-Paleocene Raman, Garzan and sinan reef carbonates, and to lesser extent, the fissured Germav shales and uppermost zones of the Lower and Middle Cretaceous Mardin carbonates constitute the reservoir rocks in southeast Turkey (figure 3). The Upper Cretaceous-

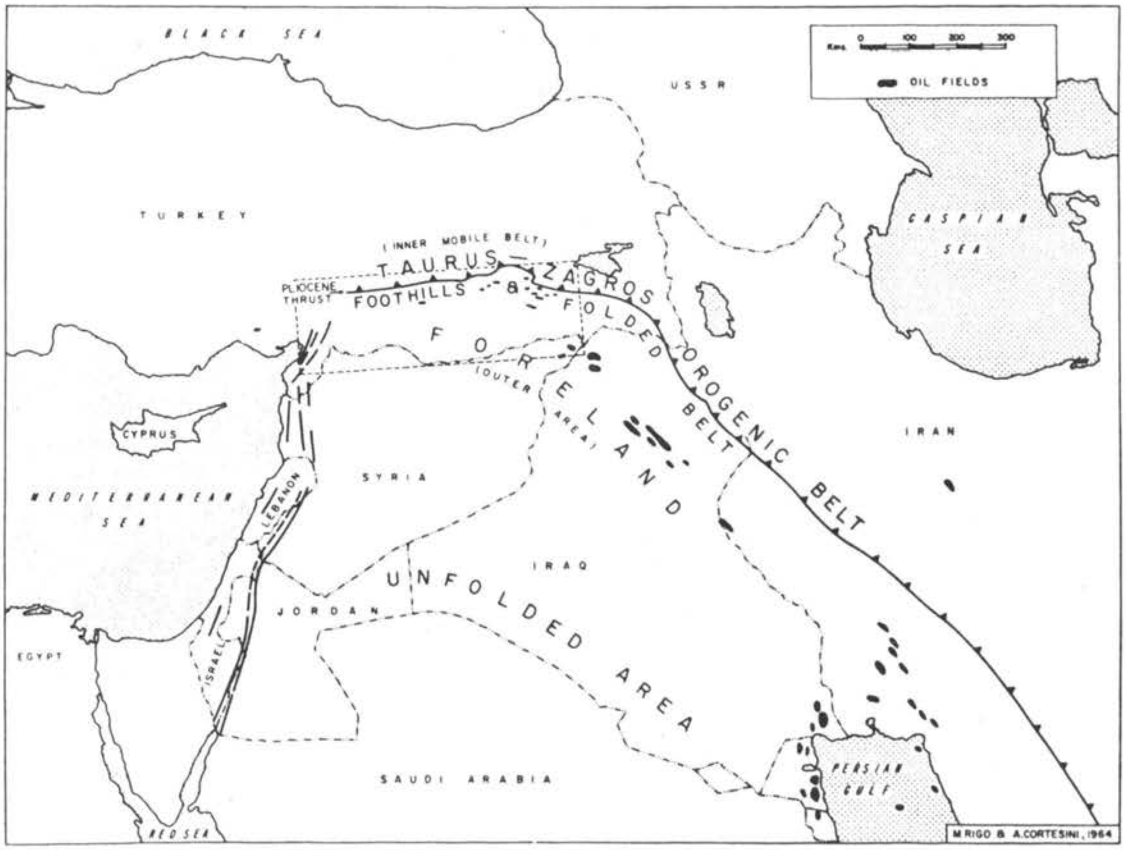

Figure 60. Generalized tectonic map of the Middle East and southeast Turkey (M. de Righi and A. Cortesini, 1964).

Paleocene Germav shales are generally considered as the main source rock. These also act as the cap rock of certain oil fields in southeast Turkey.

Oil is recovered from secondary porosity due to fracturing or weathering of the Mardin carbonates in the Diyarbakir and Adiyaman fields. Production is from primary porosity zones of the Raman, Garzan and Sinan carbonates in the Raman, west Raman, Celikli, Garzan and Magrip oil fields and from fissured Germav shales in the Kurtalan fields (figure 4).

As earlier noted the stratigraphic succession of Upper Cretaceous-Paleocene formations in the south consists of the Raman reef carbonates, Kiradag shales, Garzan reefs, lower Germav shales and marls, lower Sinan reefs, lower Germav tongue, upper Sinan reefs and upper Germav shales and graywackes overlain by the Gercus red clastics and marls. The Raman, Garzan and sinan reef carbonates gradually thin and disappear towards the northern geosynclinal area away from the marginal folds zone.

In the Foothills belt the Upper Cretaceous-Paleocene section consists of an intraformational ophiolitic mixture and overlying Antak red clastics. Although the Mardin carbonates potential reservoir rock extends further north in the geosynclinal areas, the chaotic nature and unpredictable thickness of the overlying ophiolites and the difficulty of identifying favorable petroleum structures under this complex introduce major exploration problems in the Foothills Zone. Surface thrusting is an additional factor which reduce the oil potential in this thrust belt.

In southeast Turkey oil is produced mostly from anticlinal traps. Fault traps are present in the Diyarbakir area. Elsewhere combined stratigraphic and structural traps exist such as in the Selmo field.

B. Oil potential in the research area

The studied area has a petroleum potential despite its setting within the geosynclinal zone and thrust cover area. Absence of the Upper Cretaceous intraformational ophiolites, presence of potential reservoir horizons, and gentle folds within the autochthonous Tertiary sediments are considered favorable factors. On the other hand the thickness of geosynclinal sediments, facies change of the reef reservoir horizons into open sea limestones and marls to the north, and the presence of thrust sheet cover are among the unfavorable factors.

1. Stratigraphic aspects

The Upper Cretaceous intraformational ophiolite mixture was encountered under the Antak red clastics in the Golap drill hole in the northwest corner of the mapped area. However, this same complex mixture was not cut in the Alicli drill hole, east of Kozluk about 40 kms southeast of the Golap locality (figure 22). At the Alicli drill hole the Upper Cretaceous-Paleocene sequence consists of shales with reef carbonate intercalations. This is the typical Upper Cretaceous-Paleocene sequence of the Borderfolds Region.

The Alicli borehole is located on the Oligocene-Miocene hinge between the Selmo marginal and Lice-Baykan northern geosynclinal basins The hinge zone across which the Upper Cretaceous-Paleocene sediments change from marginal basin into geosynclinal facies, must be further north than the Oligocene-Miocene hinge belt (figure 38).

The southern front of the intraformational ophiolite mixture trends east-northeast north of the Hazro uplift and Golap localities outside the mapped area. The projection of this line is just north of Sason. On this basis it may be expected that south of this line the typical Upper Cretaceous-Paleocene section of southeast Turkey will be encountered in drill holes within the thrust covered Sason-Baykan area.

The lithology of the Upper Cretaceous-Paleocene formations drilled at the Alicli locality indicate a gradual deepening of the basin towards the north. The Sinan, Garzan and Raman carbonates are micritic and shaly. The clastic portion of the Upper Cretaceous-Paleocene section at Alicli consists mainly of green shales and sandstones which contrast with the coarse red clastics encountered in the Golap drilling to the west. The deepening of the basin and resultant sediment change may have been confined to an area north of the Baykan-Sason region. The presence of flysch-type sediments under the Midyat equivalent Eocene marker bed within the allochthonous block also suggest that the Paleocene-Eocene basin was relatively deeper in the northern Baykan-Sason area.

The postulated deepening of the basin has two implications:

1) The shallow marine reef Sinan, Garzan and Raman carbonates are expected to change into open sea limestone and marls to the north of the Alicli-Melefan line.

2) The Paleocene clastic overburden on these reservoir horizons should increase in thickness towards the north. The northward increase in thickness is confirmed by 829 meters of Paleocene-Eocene clastics overlying the upper Sinan reef carbonate in the

Alicli borehole in comparision to 450 meters at the Habanidere and Selmo boreholes a few kms south of the thrust front and just south of the mapped area.

The hinge zone apparently began to rise after Eocene time while the northern and southern basins began downwarping. This resulted in post-Eocene sediments having minimum thickness along the hinge belt and a rapid increase in thickness south and north away from the Oligocene-Miocene hinge zone. Post-Eocene sediments are only 624 meters thick at the Alicli locality compared to about 1400 meters at the Habanidere locality a few kms south and 1650 meters at the Yazpinar drilling about 10 kms northeast. Likewise the Lice sediments are only 50-100 meters thick on the Golap and Belaso anticlines, which represent the hinge belt west of the mapped area, compared to some 1100 meters on the northern flanks of this hinge towards Cacas.

The hinge zone within the mapped area appears to have the highest petroleum potential from a stratigraphic point of view. The potential Sinan, Garzan, Raman as well as Mardin carbonate reservoir rocks are present in the zone and the thickness of the overburden and thrust cover is minimum. Further north of this zone, only the Mardin carbonates remain as a potential petroleum-bearing horizon because of expected facies change in the reef carbonates. The thickness of overburden and thrust sheets increases to the north and fenstern exposing the lower block are rare or absent.

2. Structural aspects

In contrast to the relatively complex structures of the allochthonous block, the underlying autochthonous Tertiary sediments are only gently folded in the Sason-Baykan area. Examples are the Golap and Belaso anticlines to the west and the Dodan and Tavan anticlines to the east (figure 38) which partially crop out under the thrust sheets. In general, the gently warped thrust sheets are a reflection of the underlying fold structures. Fenstern occur along the axial portion of the underlying anticlines with the Maneran and Goh fenstern as good examples (plate 2).

The Oligocene-Miocene hinge belt also has the highest petroleum potential from a structural point of view. Early formed structures, which correspond to gravity anomalies and indicate basement involvement have higher oil potential than the superficial folds formed during the Late Miocene orogeny. As noted, the hinge zone is an uplift in the Sason-Melefan area which began to form soon after Eocene time.

Three major gravimetric anomalies occur along the hinge zone (Ivanhoe, 1967). The Golap anomaly is located in the Hamzali, Herip, Tanzi area (plate 3). The highest point of the anomaly is a few kms southeast of Hamzali on the axis of the Golap anticline. The Sason anomaly occurs in the Gemik-Rabat-Musritan area. The highest point of this anomaly is 2 kms north of Rabat (plate 1). Another high point occurs 2 kms east of Gemik (plate 2). The third anomaly, the Melefan, is north of Melefan between Dilbe, Ayingavis and Memla. The highest portion of this anomaly occurs 2 kms north of Melefan (plate 4). Each of the above gravity anomalies lie along a northwest trending zone coincident with the hinge belt in the area.

The hinge zone is not a single elongate uplift. Its form approximates a simple anticlinorium. The Golap-Belaso anticlines on the west and the Dodan-Tavan anticlines to the east are part of this hinge zone. A certain degree of coincidence exists between the gravity anomalies and these anticlines. This suggests that both the Sason, and Melefan anomalies are reflections of underlying structural highs even though surface indications, such as folding of the upper thrust plates, are somewhat meagre.

Some stratigraphic evidence also suggests that the area north of Melefan in the vicinity of the Melefan gravimetric anomaly is located on a domelike structural high in the underlying block. The saline phase of the Selmo evaporites, as well as the thick red clastics of Karatepe subgroup are confined to this area. These grade northeast and northwestward into deeper marine facies. Likewise Lice graywackes and shales are only 160 meters thick at the Yazpinar borehole north of Memla and 1384 meters thick at the Meselik locality about 10 kms northeast of Yazpinar (figure 22).

Additional exploration work north of the Musritan-Gemik area where the Sason and Melefan anomalies occur, may be worhwhile. Known anticlinal structures under the thrust cover, such as the Sason and Maneran anticlines (plate 2), are also somewhat favorable. Fenstern occur along the axial portion of the Maneran and Sason anticlines and Sason flysch crops out from underneath the metamorphic rocks (figures 45 and 48). Both the Maneran and Sason anticlines are clearly reflected in the gentle upwarping of the thrust plates.

In addition to fold structures clearly reflected by the broad upwarping of the overlying thrust plates, other fold structures may exist within the underlying authochthonous block and yet not be obviously reflected above. Dipmeter surveys at the Alicli drill hole by the Turkish Petroleum group indicate southward dips and the possible presence of anticlinal structures to the north. The Selmo beds which crop out in the Alicli fenster are highly contorted due to thrusting. This surficial deformation obscured possible surface indications of an underlying fold structure. Here the thrust plates do not reflect a possible underlying structure such as is the case of the Sason and Maneran anticlines. Nevertheless, the western projection of Dodan axis (figure 38) runs through about 1 km north of the Alicli bore hole where constant southward dips are indicated. Hence although totally obscured on the surface an anticlinal structure is most probably present at this locality. Structural contour maps of the Sason and Baykan thrust faults may reveal obscure upwarps which may reflect underlying anticlinal structures within the autochthonous block.

VII. CONCLUSIONS

Significant conclusions from this study relate to change in age dating of some stratigraphic units, the basins of deposition, character and depth of sediment accumulation, tectonic developement, structural characteristics of the area and the oil potential. Major conclusions are listed below.

1. Contrary to earlier and rather general beliefs, the eugeosynclinal basins and submarine volcanic activity associated with such basins are not confined to Upper Cretaceous-Paleocene time in Turkey. The allochthonous eugeosynclinal sediments and accompanying serpentine and spilites are Oligocene to Miocene age in the Sason-Baykan area.

2. The focus line of the orogenic zone migrated southward in time. Earlier geosynclines existed on the Bitlis Massif during Upper Cretaceous-Paleocene time. The southern frontal portions of the Massif began downwarping as uplift commenced to the north after a quiet Eocene epoch. Eogeosynclinal conditions developed in this frontal Lice-Baykan trough in Oligocene-Miocene times.

3. This northern Lice-Baykan trough was linked to a southern marginal basin by a northwest trending hinge zone which had the characteristics of an elongate uplift by Oligocene time.

4. Oligocene-Miocene sedimentation within the northern geosynclinal and southern marginal basins can be divided into an earlier dominantly non-clastic and later dominantly clastic stages. South to north facies change of the sediments reflects changing tectonic environments. While evaporites and red sandstones deposited in the southern marginal basin, red marl, micrite, chert and flysch deposited in the northern eugeo-

syncline with accompanying basic volcanic activity.

5. The Lice graywackes, shales and marls are not molasse-type post-tectonic basin sediments, but constitute the southern outer flank association of the Oligocene-Miocene Lice-Baykan geosyncline. Similarly the allochthonous Sason-Baykan group constitutes the inner rim and axial eugeosynclinal deposits of the same trough. Germik and Selmo evaporites and Silvan reef limestone were deposited in the southern marginal basin and on the hinge zone between the two basins.

6. The Lice outer flank sediments were thrust over the Selmo and Germik marginal basin deposits along the Lice thrust. The Sason-Baykan sediments were thrust southward over the Lice group along the Baykan thrust and were in turn thrust over by the massive plate of metamorphic rocks along the Sason thrust during the Late Miocene orogeny.

7. Diastrophic movement also shifted from north to south similar to the migrating basin and uplift. The Kale thrust formed first in the north where the Upper Cretaceous-Paleocene basins had been present. Later, Sason, Baykan and Lice thrusts, which involved the frontal geosyncline sediments, occurred further south.

8. Although major diastrophism took place at the end of Miocene, some field data suggest that the northern Kale thrust occurred earlier, possibly in Oligocene time.

9. Thrust faults are the major structural elements. However, the metamorphic rocks and crystalline limestones of the allochthonous massif appear to have formed an overturned fold structure in the Sason area. The upper limb was displaced 20 kms further south as a tongue of the Sason thrust in the Sason-Kozluk area.

10. Tangential compression was the principle driving mechanism of deformation. The principle stress axis was oriented north-south. Folding was initiated long before and continued during and after thrust faulting. A tensional stage followed compression and east-west normal faults formed.

11. Although a number of exotic limestone and serpentine blocks lie within the geosynclinal sediments, contrary to the general belief, submarine gravity sliding played a minor role in outlining the structure of this area.

12. Surface evidence for large scale underthrusting related to possible plate tectonics for this area is lacking.

13. Serpentines and spilites are associated with both flysch-type sediments and littoral to sublittoral clastic and non-clastic sediments in the area suggesting that abyssal depths for serpentine formation are not necessary.

14. Despite its setting within a geosynclinal zone, the area does have oil potential. Absence of Upper Cretaceous intraformational ophiolitic mixture, presence of reservoir horizons, and gentle folding within the autochthonous Tertiary sediments under the thrust cover, and the surficial horizontal nature of the thrust faults are favorable factors.

15. The thrust plates are gently warped in conjuction with the underlying folds within the autochthonous block. Structural contour maps of the Sason and Baykan thrust planes may reveal some obscure upwarps and hence underlying fold structures.

16. Both the structural and stratigraphic field evidence

suggest that the greatest oil potential exist along the hinge belt between the Oligocene-Miocene marginal basin and the northern geosyncline in the Sason-Baykan area. Some known structures and the Golap, Sason and Melefan gravimetric anomalies are located on this hinge with a minimum thickness of overburden.

17. Increase in thickness of the overburden and change of facies of the potential reservoir horizons to the north reduces the petroleum potential in this direction.

18. Finally, part, if not all of the massive limestone-dolomite group which constitute the uppermost unit of the allochthonous block may well be of Cretaceous rather than Permian age.

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VITA

Ismail Ozkaya was born in Turkey in 1943. He received his primary education at different localities within the country, and graduated from the Yenimahalle men's high school (Mustafa Kemal lisesi) in 1961.

He began his study of geology and geological engineering at the Middle East Technical University in Ankara in 1961 and obtained a B. S. degree in Geological Engineering in 1966. He received an M. S. degree in Geological Engineering in 1967 from the same Institution.

He joined the Mineral Research and Exploration Institute of Turkey for a half year in 1968, after which he returned to the Middle East Technical University as a teaching assistant in the Department of Mining and Geological Engineering.

Under the sponsorship of the Scientific Research Council of Turkey, He came to the United States in August 1969. Here he enrolled in the Graduate School of the University of Missouri-Rolla and continued his studies towards a Ph. D. degree in Geology.

He is a member of the American Society of Photogrammetry and Society of Exploration Geophysicists. He is also a member of the honorary scholastic society of Phi Kappa Phi.

APPENDIX I

Thin section study of samples from southeast Turkey

The following are thin section study of 14 rock samples from the Sason-Baykan and Lice areas by Dr. Orville L. Bandy, Professor of Geology and Micropaleontologist of the University of Southern California.

Sample number: E-6

Location: I km north of Dere, west of Sason.

Stratigraphic location: A red marl bed within the upper red marl-clastic sequence of the Baykan group.

Reference: Plate 2, map/L46-b4, unit 6 of figure 25.

Description: Possible Paleocene or Lower Eocene. Planktonics dominant, composing more than 95 % of the fauna. This suggests a deep water environment of deposition (bathyal most likely). Globigerinids are common, some may be Morozovella. Some radiolarians noted.

Sample number: E-2

Location: I km north of Dere, west of Sason.

Stratigraphic location: Sason flysch.

Reference: Plate 2, map/L46-b4, unit 2 of figure 25.

Description: Nondiagnostic. Bioclastic debris rare. Glauconite and sand noted.

Sample number; J-4

Location; I km east of Sason.

Stratigraphic location: Sason flysch.

Reference: Plate 2, map/L46-b3, unit 6 of figure 26.

Description: Probably Paleocene or Lower Eocene? Planktonics dominant. Probably a bathyal environment of deposition. Morozovella and Globigerinids common.

Sample number: 5

Location; North of Melefan, a point between Gemazen tepe and Navalan tepe.

Stratigraphic location: Intrasparites of the upper red marl-clastic sequence of Baykan group.

Reference: Plate 4, map/L47-dl, unit 14 of figure 27.

Description: Age uncertain, probably Oligocene-Miocene? Lepidocyclina sp. and calcareous algae suggest very shallow water deposition.

Sample number: 6

Location; North of Melefan, from Gemazen tepe.

Stratigraphic location: Micrites of the upper red marl-clastic sequence of Baykan group.

Reference: Plate 4, map/L47-dl, unit 13 of figure 27.

Description: Nondiagnostic.

Sample number: H-l

Location: North of Ziyaret, west of Homent.

Stratigraphic location: A sandy limestone within Lice group.

Reference: Outside of the mapped area.

Description: Age uncertain. This calcarenite contains poorly preserved speciments of various fossils. Some are fragments of Melobesia, rotalid foraminiferans, and there may be a poorly preserved fragment of *Discocyclina*. The fauna reflects a shallow water environment, or it could be a displaced fauna in somewhat deeper water.

Sample number; H-5

Location: North of Ziyaret, near Homent.

Stratigraphic location: The marker limestone layer equivalent of the Midyat neritic limestones.

Reference: Outside of the mapped area, unit 4 of figure 28.

Description: Probably Lower or Middle Eocene micrite. *Nummulites*, *Alveolina*, *Discocyclina*, and bryozoa noted. These are dominant and suggest a shallow water environment, probably between 0 and 80 meters.

Sample number: C-4

Location: South of Destumi, about 500 meters west of Bitlis road.

Stratigraphic location: The marker limestone bed of the Baykan group equivalent of the neritic Midyat limestones.

Reference: Outside of the mapped area, unit 4 of figure 29.

Description: Age uncertain, possibly Eocene based on a poorly preserved form that may be *Dictyoconus*.

Sample number: D-3

Location: West of Minar, north of Dodan anticline.

Stratigraphic location: The marker limestone bed of the Baykan group equivalent of the neritic Midyat limestones.

Reference: Outside of the mapped area, unit 17 of figure 30.

Description: Probably upper part of Lower Eocene or Middle Eocene (micrite), Alveolinids, Nummulites, and possibly Apertorbitoides (?) occur.

Sample number: 33

Location: North of Rabat, Rabat Kalesi tepe.

Stratigraphic location: Nummulitic limestone bed uppermost layer of an outlier of sediments on allochthonous metamorphic rocks, identical to neritic Midyat limestone.

Reference: Plate I, map/L46-cl, unit I of figure 9.

Description: Eocene micrite. Nummulites, Discocyclina and related forms common. One species may be Discocyclina discus? This could be Upper Eocene. These suggest a shallow water environment, probably between about 0 and 80 meters.

Sample number: I

Location: South of Musritan, a point between Seyhfethettin tepe and Gevrigari tepe, south of Maaztasi tepe.

Stratigraphic location: Unknown, an interthrust of sediments within calc-schists.

Reference: Plate I, map/L46-cl.

Description: Probably Lower or Middle Eocene. Melobesia, Alveolines and Discocyclina noted. Shallow water biofacies, probably an environment in the 0 to 80 meters depth range.

Sample number: I-I

Location: South of Herent, and west of Ismailkan, on the west side of Sason road.

Stratigraphic location: Calcareous coarse sandstones of the Lice group.

Reference: Plate I, map/L46-cl.

Description: Uppermost Oliocene or Lower Miocene? Lithothamnion and Miogypsinids noted. These suggest shallow water conditions in the 0 to 80 meter depth range.

Sample number. L-I

Location; I km north of Lice.

Stratigraphic location: Exact stratigraphic location unknown, probably lowermost portions of Lice group or equivalent of Silvan limestone. A limestone layer that overlies a serpentine wedge.

Reference: Outside of the mapped area, unit 5 of figure 23.

Description: Age uncertain. This is a micrite with pellets, radiolarians, globigerinids, and rare specimens of benthic foraminiferans and echinoid debris. As a pelagic facies it has more in common with E-6 and J-4.

Sample number: L-4

Location: I km north of Lice.

Stratigraphic location: Exact stratigraphic location unknown, probably lowermost portion of Lice group. A limestone layer of the sedimentary section that overlies a serpentine wedge.

Reference: Outside of the mapped area, unit 6 of figure 23.

Description: Probably uppermost Oligocene or Lower Miocene. Lithothamnion, Amphistegina, Lepidocyclina, and Miogypsina suggest very shallow water.

APPENDIX 2

Radioactive age determinations

The following are the result of the radioactive age determinations of two spilite samples from the allochthonous geosynclinal sediments of the Sason-Baykan area by the Geochron Laboratories Division, Krueger Enterprises Inc., Cambridge, Massachusetts, USA.

Sample number: 1

Location: North of Memla.

Stratigraphic position: Spilites within the lower red marl-clastic sequence of the Baykan group, at a higher stratigraphic level than the Eocene marker limestone bed.

Reference: Plate 4, map/L47-d1, unit 7 of figure 27.

Absolute age: 35.6 $\pm$ 1.8 Million Years (Oligocene).

Sample number: 2

Location: East of Sason.

Stratigraphic position: Spilites within the Sason flysch. Stratigraphic position with respect to the Eocene marker bed is not known.

Reference: Plate 2, map/L46-b3, unit 5 of figure 26.

Absolute age: 33.2 $\pm$ 2.6 Million Years (Oligocene).

(See official document following)

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2321 | **Date Received:** 15 June 1972

Your Reference: Sample #1 | **Date Reported:** 24 July 1972

Submitted by:
Ismail Ozkaya
Dept. of Geology
University of Missouri-Rolla
Rolla, Mo. 65401

Sample Description & Locality: Spilite

Material Analyzed: Whole rock, crushed to -40/+100 mesh.

Ar^{40*}/K^{40} = .002101 | AGE = 35.6 ± 1.8 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.002937	.309	.002693
.002381	.302	
.002762	.265	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.065	1.051	1.282
1.037		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

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POTASSIUM-ARGON AGE DETERMINATION **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2322 **Date Received:** 15 June 1972

Your Reference: Sample #2 **Date Reported:** 24 July 1972

Submitted by: Ismail Ozkaya
Dept. of Geology
University of Missouri-Rolla
Rolla, Mo. 65401

Sample Description & Locality: Spilite

Material Analyzed: Whole rock, crushed to -40/+100 mesh.

Ar^{40*}/K^{40} = .001962 AGE = 33.2 ± 2.6 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.001074	.157	.000905
.000722	.122	
.000918	.143	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
.382	.378	.461
.374		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

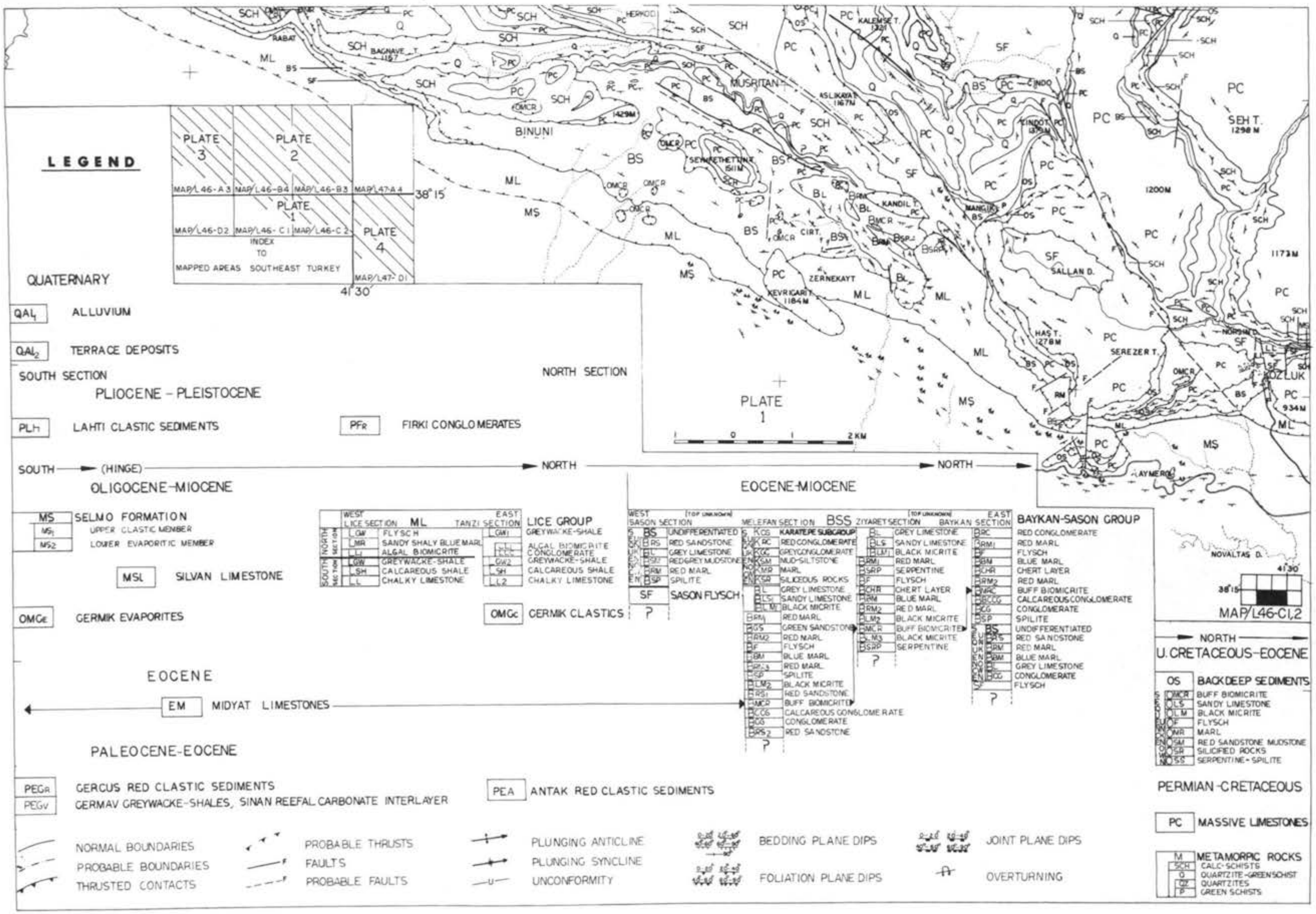

Plate I. Geologic map of Kozluk-Rabat area.

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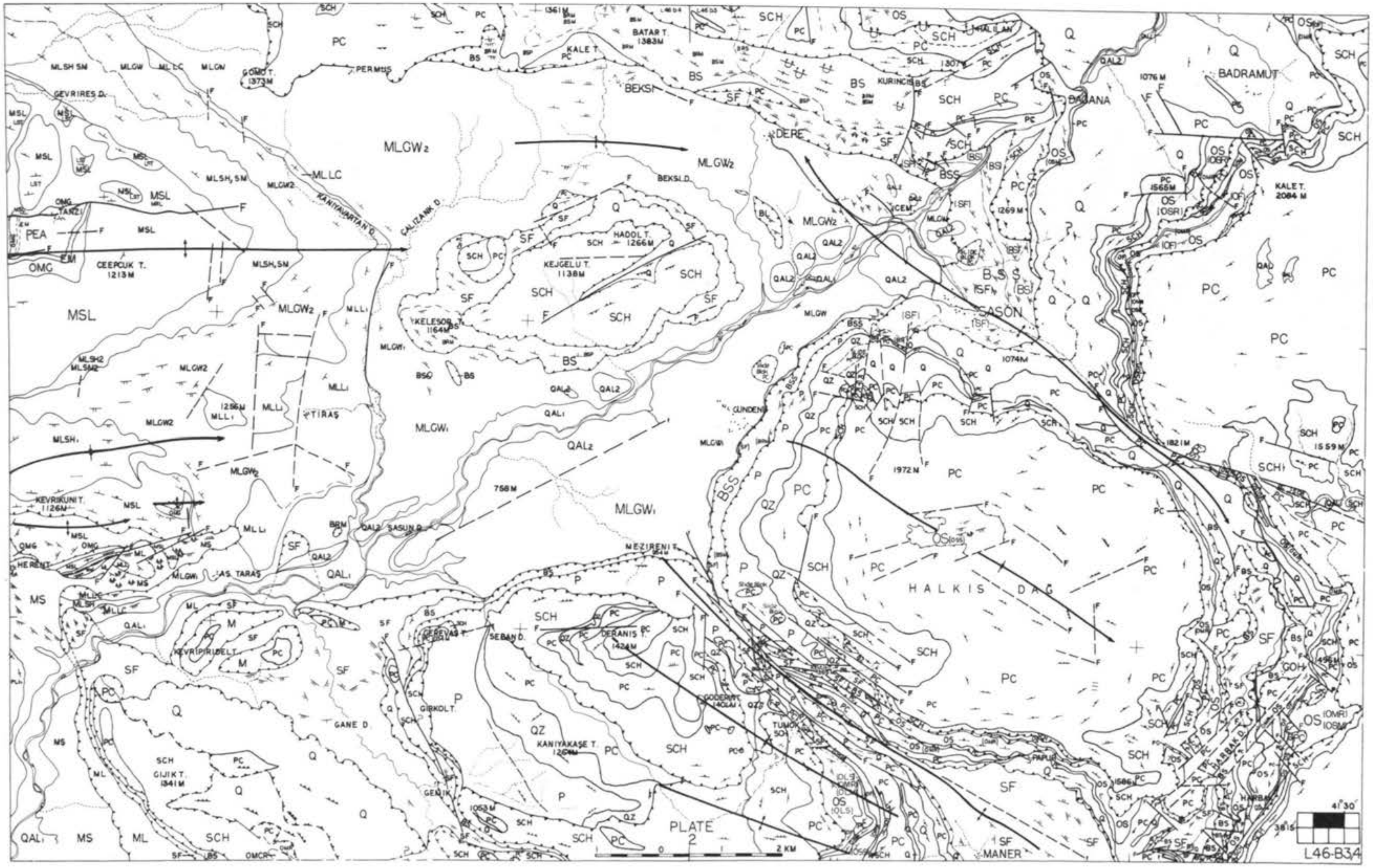

Plate 2. Geologic map of Sason-Harbak area.

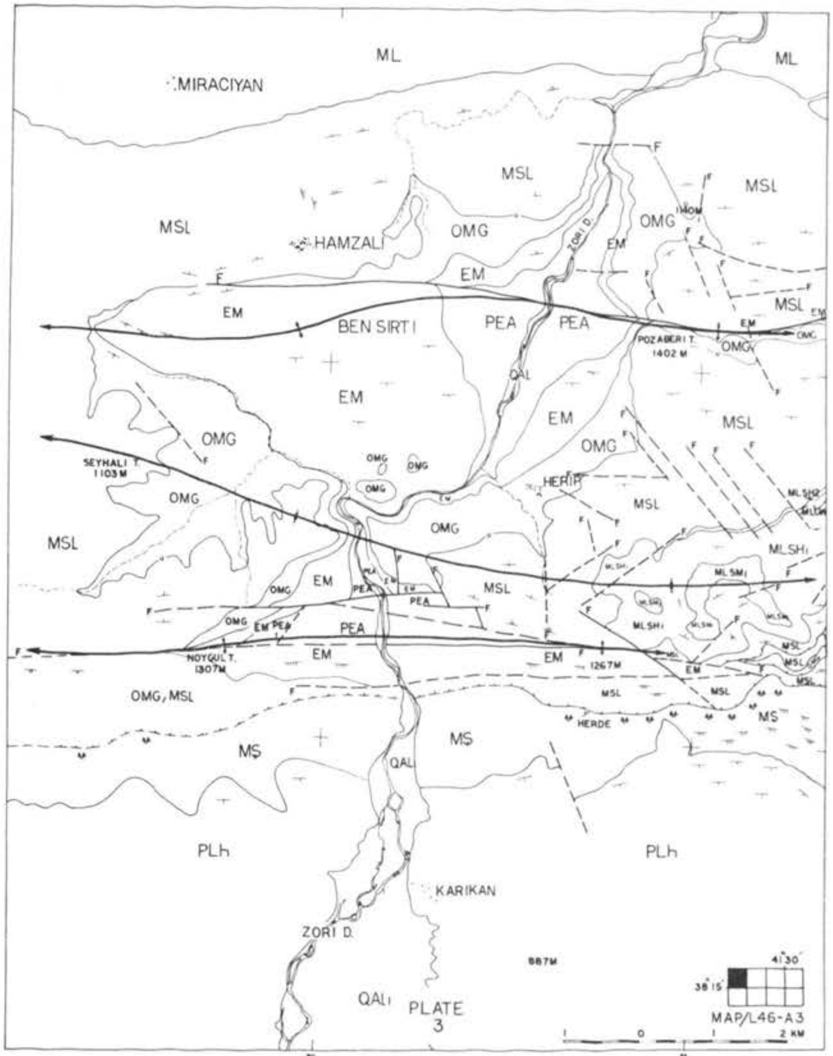

Plate 3. Geologic map of Hamzali area.

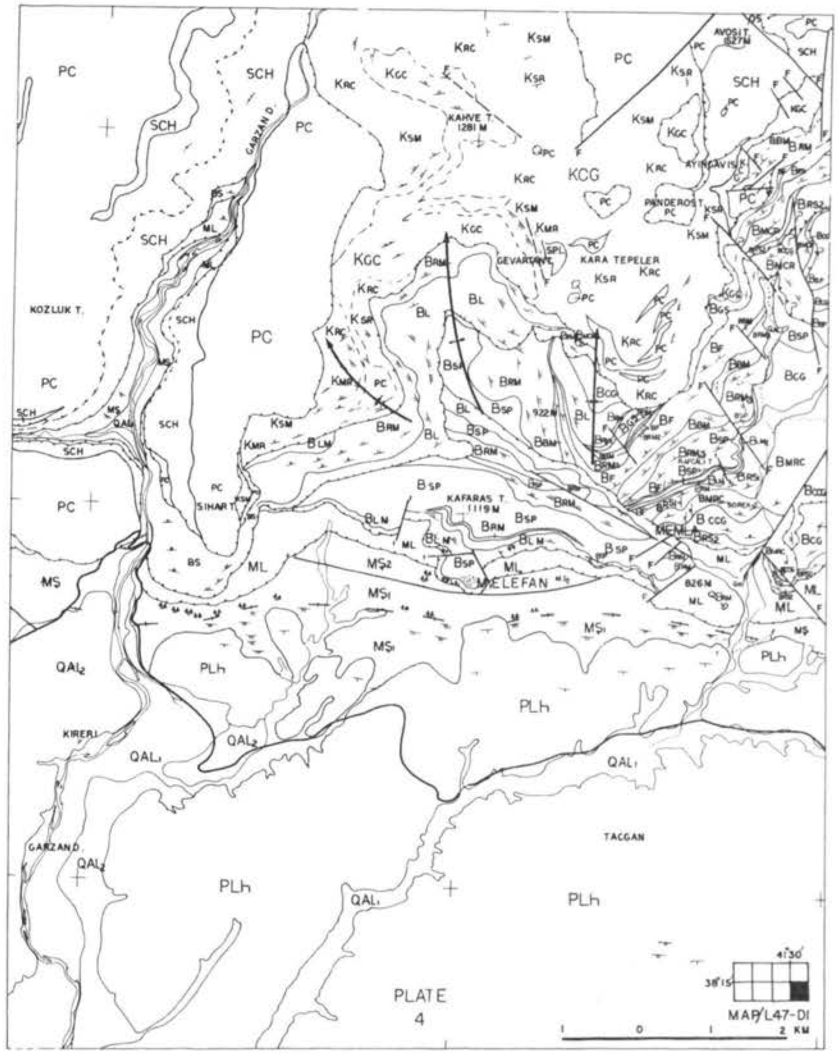

Plate 4. Geologic map of Melefan area.